protection limits and guidance. Any potential radiation exposure from radon or other sources would be of limited duration and any potential radiation dose would be expected to be very low.

7.5.3 HYDROLOGY/GEOLOGY

7.5.3 (1212)
Comment - EIS000322 / 0003
Besides the deadly threat of transportation of this high-level radioactive waste, the storage of the waste in Yucca Mountain also poses a threat to us all. Yucca Mountain is volcanic, it is seismically active, and it will leak. Studies have been done that indicate Yucca Mountain has been flooded with hot water in the past.

Response
Based on the results of analyses in Chapter 5 of the EIS on the long-term performance of the proposed repository at Yucca Mountain, DOE believes that a repository would operate safely (in compliance with the Environmental Protection Agency's Environmental Radiation Protection Standards in 40 CFR Part 197). Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 of the EIS describes the potential impacts from accident scenarios associated with earthquakes during repository operations. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. DOE believes that the EIS adequately describes and analyzes geology, geologic hazards, and the effects of these hazards on the proposed repository.

Section 3.1.4.2.2 of the EIS describes evidence that the elevation of the water table at Yucca Mountain has fluctuated over time. These fluctuations have been due primarily to changes in the climate. DOE examined the cumulative effects on the elevation of the water table from a wetter climate, earthquakes, and a volcanic eruption. Based on the evidence, no reasonable combination of wetter climates, earthquakes, and volcanic eruptions could raise the elevation of the water table sufficiently to inundate the waste emplacement areas at Yucca Mountain.

There is no evidence to suggest that the water table at Yucca Mountain is slowly rising. Section 3.1.4.2.2 (Saturated Zone) discusses opposing views on fluctuations in the elevation of the water table. A small number of investigators believe that the water table has risen in the past to elevations higher than the waste-emplacement areas. DOE does not concur with these views, nor did an expert panel that the National Academy of Sciences convened to examine this issue (as described in Section 3.1.4.2.2). DOE believes that the geologic evidence strongly indicates that past water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than present for the past several million years.

7.5.3 (1376)
Comment - EIS000432 / 0004
Furthermore, there is also surface and ground water that flows near the proposed site at Yucca Mountain. For example, the Fortymile Canyon river/waterway flows just east of Yucca Mountain itself. The Buckboard waterway flows from the north. The [Amargosa] River flowing from the west alongside Yucca Mountain down to the south of Yucca Mountain. The DOE also states that "In the distant future groundwater would contain small quantities of radionuclides and chemical toxic substances." (s-42) Again the DOE says that the impact on plants and animals would be small and "unlikely" to have adverse impacts.

Response
Section 3.1.4.1 of the EIS describes surface water in the area of Yucca Mountain in detail. The Amargosa River and its tributaries (including Fortymile Wash) are dry along most of their lengths most of the time. The Central Death Valley hydrologic subregion consists of three groundwater basins, each with smaller sections. Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin. Hydrologic models derived from extensive studies indicate that water infiltrating at Yucca Mountain would join groundwater in the Fortymile Canyon section and flow toward the Amargosa River section (see Figure 3-13). Thus, the small fraction of water of the total in the basin that might move through a repository would be likely to flow toward the south toward Amargosa Valley. Long-term performance assessment (modeling) analyses indicate that the combination of the natural barriers of the repository site and engineered barriers would keep the radionuclides well below the regulatory limits established at 40 CFR Part 197. Sections 3.1.4.2.1 and 5.4 of the EIS contain more information.

7.5.3 (1486)
Comment - 010290 / 0004
The SDEIS introduces the concept of fuel pools for blending waste at Yucca Mountain. Fuel pools will introduce new risks that have not been adequate analyzed, particularly in relation to seismicity. Also, fuel pools will require huge quantities of water -- a precious resource in the desert. The SDEIS assumes that water will be available from the State of Nevada, although the State has denied water appropriations for the Yucca Mountain Project. The DOE should assess the feasibility and impact of importing water from another source.

Response
As discussed in Section 3.1.3.3 of the EIS, DOE has been monitoring seismic activity and studying the geologic structure at and near Yucca Mountain since 1978. Using these data and the results of these studies, along with input from panels of recognized experts on seismic risks and hazards, DOE would design critical surface facilities at the repository to withstand a magnitude-6.3 earthquake within 5 kilometers (3 miles) of Yucca Mountain (this bounds the effects from a magnitude-7.5+ earthquake in Death Valley within 50 kilometers (31 miles) of Yucca Mountain). Similarly, possible fuel blending in the Waste Handling Building would be designed to withstand such earthquakes.

The highest estimate of water demand for the flexible design described in the Supplement is less than the highest estimate for water for the design described in the Draft EIS (see Table S-2 of the Supplement). On February 2, 2000, the Nevada State Engineer denied DOE's water-appropriation request for 430 acre-feet per year for repository construction and operation (DIRS 144853-Turnipseed 2000). The State Engineer based his denial on a finding that the requested use threatened to prove detrimental to the public interest. On March 2 and 3, 2000, DOE filed suits in U.S. District Court for the District of Nevada and in Nevada's Fifth Judicial District Court, respectively, for injunctive relief to overturn this Ruling. On September 21, 2000, the U.S. District Court Judge granted the State's motions to dismiss the DOE lawsuit. DOE appealed this ruling on November 16, 2000. On October 15, 2001, the Ninth U.S. Circuit Court of Appeals ordered a Federal judge to hear the DOE's suit. The case is pending.

DOE has not developed any other plans to acquire water for the proposed repository. Depending on the final ruling of the State Court, DOE might consider other options to carry out its responsibilities under the Nuclear Waste Policy Act, as amended.

7.5.3 (1770)
Comment - EIS000572 / 0002
Everything has been thrown out the window, all their guidelines, everything. I mean, this is like active volcanoes, you know. We have earthquakes, but they are only one, two, three. Still, there are earthquakes, which means there can be bigger ones, you know, that will affect the repository, and it will affect everybody in this area.

Response
DOE has not proposed to amend its general guidelines (10 CFR Part 960) to avoid the elimination of the Yucca Mountain site from consideration. Rather, the purpose of the new Yucca Mountain-specific guidelines (10 CFR Part 963) is to implement the NWPA, given the regulation and criteria of the Environmental Protection Agency (40 CFR Part 197) and the Nuclear Regulatory Commission (10 CFR Part 63) and to provide a technical basis to assess the ability (or performance) of a geologic repository at Yucca Mountain to isolate spent nuclear fuel and high-level radioactive waste from the environment.

The Nuclear Waste Policy Act of 1982 [Section 112(a)] directed the Secretary of Energy (and by extension, DOE) to issue general guidelines for the recommendation of sites for characterization, in consultation with certain Federal agencies and interested Governors, and with the concurrence of the Nuclear Regulatory Commission. These guidelines (issued in 1984 at 10 CFR Part 960) were to include factors related to the comparative advantages among several candidate sites located in various geologic media, and other considerations such as the proximity to storage locations of spent nuclear fuel and high-level radioactive waste, and population density and distribution.

In 1987, amendments to the Nuclear Waste Policy Act specified Yucca Mountain as the only site DOE was to characterize. For this reason, DOE proposed in 1996 to clarify and focus its 10 CFR Part 960 guidelines to apply only to the Yucca Mountain site (draft 10 CFR Part 963), but never issued these guidelines as final. In 1999, DOE proposed further revisions to the draft Part 963 guidelines for three primary reasons:

1. To address comments that criticized the omission of essential details of the criteria and methodology for evaluating the suitability of the Yucca Mountain site.

2. To update the criteria and methodology for assessing site suitability based on the most current technical and scientific understanding of the performance of a proposed repository, as reflected in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998).

3. To be consistent with the then-proposed site-specific licensing criteria for the Yucca Mountain site issued by the Nuclear Regulatory Commission (which has since promulgated these criteria at 10 CFR Part 63), and the then-proposed site-specific radiation protection standards issued by the Environmental Protection Agency (which has since promulgated these standards at 40 CFR Part 197).

In 2001, DOE promulgated its final 10 CFR Part 963 guidelines to establish the methods and criteria for deterring the suitability of the Yucca Mountain site for the location of a geologic repository. These final guidelines are principally the same as those proposed in 1999.

Chapter 5 of the EIS considers the effects of future earthquakes on the long-term performance of the proposed repository at Yucca Mountain. Based on the results of those analyses, DOE believes that a repository would operate safely (in compliance with the radiation protection standards in 40 CFR Part 197). Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes potential impacts from accident scenarios associated with earthquakes during repository operations. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. DOE believes that the EIS adequately describes and analyzes the geology, geologic hazards, and the effects of these hazards on the repository.

7.5.3 (1820)
<u>Comment</u> - EIS000198 / 0001
After seeing some of the pictures put out by the DOE we clearly show the path of groundwater passing under Yucca Mountain with all its geological faults and eventually passing to the inhabitants of Amargosa Valley and being in an earthquake zone. Why are you doing this?

<u>Response</u>
Based on the results of analyses in Chapter 5 of the EIS on the long-term performance of the proposed repository at Yucca Mountain, which considered the effects of existing fractures on groundwater flow and future earthquakes, DOE believes that the repository would operate safely. DOE recognizes that some radionuclides and potentially toxic chemicals would, after long periods, enter the environment outside the repository. Nevertheless, modeling of the long-term performance of the repository indicates that the combination of natural and engineered barriers would keep such releases within the regulatory limits established by 40 CFR Part 197. As described in Chapter 1 of the EIS, Congress determined, through the passage of the Nuclear Waste Policy Act of 1982, that the Federal Government has the responsibility to permanently dispose of spent nuclear fuel and high-level radioactive waste to protect the public health and safety and the environment. In the 1987 amendments to the Act, Congress directed DOE to determine whether Yucca Mountain is suitable for a geologic repository.

7.5.3 (1846)
<u>Comment</u> -- EIS000367 / 0002
I'm not sure what studies have been done on the environment as it changes. People here have mentioned volcanoes, earthquakes. Those are realities, and that's where we live. That's why Inyo is called "Land of Many Spirits," because of all these natural things and the spirits that we call them. That's the natural things of nature.

Those actions that nature has, including volcanoes, earthquakes, storms, ice ages, those are things that we have to consider in all parts of life.

Response
Chapter 5 of the EIS considered the effects of future earthquakes, volcanic eruptions, and changes in the climate on the long-term performance of the proposed repository at Yucca Mountain. Based on the results of those analyses, DOE believes that a repository would operate safely [in compliance with the Environmental Protection Agency's Environmental Radiation Protection Standards at 40 CFR Part 197. Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including volcanoes, earthquakes, and reasonable fluctuations in the climate during the next million years. Section 3.1.2.2 characterizes the climate of the Yucca Mountain area, including the frequency and severity of storms and tornadoes. As described in Section 4.1.3.2 and in Appendix L, DOE would design the site to accommodate the flow of floodwaters safely across the site.

7.5.3 (1894)
Comment - EIS000455 / 0008
Other issues are not adequately discussed in the DEIS, including ground water upswelling, earthquakes at the repository site. Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically, as much as 330 feet. All of these things need to be examined and more.

Response
There is no evidence to suggest that the water table at Yucca Mountain is slowly rising. Section 3.1.4.2.2 (saturated zone) discusses opposing views on fluctuations in the elevation of the water table. A small number of investigators believe that the water table has risen in the past to elevations higher than the waste-emplacement areas. DOE does not concur with these views, nor did an expert panel that the National Academy of Sciences convened to examine this issue (as described in Section 3.1.4.2.2). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level.

Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes potential impacts from accident scenarios associated with earthquakes during repository operations. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. DOE believes that the EIS adequately describes and analyzes the geology, geologic hazards, and the effects of these hazards on the repository.

7.5.3 (1899)
Comment - EIS000459 / 0002
Not only is Yucca Mountain riddled with earthquake faults but is slowing filling with geothermal waters.

Response
Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults and seismicity. Chapter 5 considers the effects of future earthquakes on the long-term performance of the proposed repository at Yucca Mountain. Based on the results of those analyses, DOE believes that a repository would operate safely [in compliance with the Environmental Protection Agency's Environmental Radiation Protection Standards at 40 CFR Part 197].

There is no evidence to suggest that the water table at Yucca Mountain is slowly rising. Section 3.1.4.2.2 (saturated zone) discusses opposing views on fluctuations in the elevation of the water table. A small number of investigators believe that the water table has risen in the past to elevations higher than the waste-emplacement areas. DOE does not concur with these views, nor did an expert panel that the National Academy of Sciences convened to examine this issue (as described in Section 3.1.4.2.2 of the EIS). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level.

7.5.3 (2261)
Comment - EIS000362 / 0002
I would also encourage you, on your way back, to consider driving north through Bishop and up to Mono Lake. As you approach Mono Lake, you'll see some very young cinder cones that some of them are only 500 years old.

When I looked in your EIS, it talked about volcanism and the basin and range having stopped about 75 thousand years ago. In all of your studies, the potential for a volcano erupting within the Yucca Mountain region seems to be dismissed as something long ago. They thought that the cinder cones around Mono Lake were quite a bit older until very recently, and now they have decided they are only 500 to 750 years old.

The USGS is sitting on volcanic activity in the caldera at Mammoth Lakes. It's my personal hope that, and I would be very disappointed, in fact, if within the next 10 or 20 or 30 years, during my lifetime certainly, we don't get a nice new cinder cone at the intersection of Highways 203 and 395 in the vicinity of the Mammoth Lakes Airport. I would really like to see that. It wouldn't be -- there are a lot of people who wouldn't. But it's not the kind of disaster that's human and manmade. It would be a natural event. It would be an act of God, and that, to me, also is indicative of the kind of activities that are happening in the Yucca Mountain region, but not as you have defined it in the 30-kilometer radius.

Response
As described in Section 3.1.3 of the EIS, the most recent volcanic eruption in the area occurred between 70,000 and 90,000 years ago about 10 miles south of the Yucca Mountain site. The next-youngest eruptions were in Crater Flat west of Yucca Mountain where four northeast-trending cinder cones developed about 1 million years ago. A panel of experts examined the data, models, and related uncertainties, and concluded that the probability of a volcanic dike disrupting the repository during the first 10,000 years after closure is 1 in 7,000 (1 chance in 70 million per year). Although extremely unlikely, a volcanic eruption through the repository could spread ash and entrained waste into the atmosphere and magma into the emplacement drifts. DOE estimated the potential impacts to the nearest population, conservatively assuming the direction and speed of wind transport of an ash plume, and determined that the impacts to public health and safety would be very small (Section 5.7.2 of the EIS). DOE also determined that magma flowing into the emplacement drifts would have minimal impacts on the long-term performance of the repository (Section 5.7.2 of the EIS).

7.5.3 (2512)
Comment - EIS002133 / 0001
This here is water that I had to buy. I buy water because I can't drink the water here. If they bring nuclear waste here for Yucca Mountain, we're definitely not going to be able to drink the water. It's already so bad. What are we going to do?

Response
DOE is very concerned about the safety of the groundwater and surface water in the vicinity of Yucca Mountain. The water quality in the Las Vegas Valley and in the vicinity of the proposed Yucca Mountain repository is safe for all human uses. The choice of whether or not to use this water for drinking is, and always will be, an individual and personal decision, usually based on taste preferences. With respect to a possible repository at Yucca Mountain, Chapter 5 of the EIS estimates the impact on water quality at several locations downgradient from the site. The conclusion of extensive scientific investigations and detailed engineering evaluations is that potential impacts to water quality from a repository at Yucca Mountain would be negligible.

7.5.3 (2625)
Comment - EIS000084 / 0006
The timing is not important. As a national park, they have an obligation to protect in perpetuity, meaning forever.

Yet the NPS (National Park Service) is not complaining. Why? Well, I was told the answer by the assistant superintendent of Death Valley National Park. She said they had been told by the US federal justice system not to file suit against another branch of the Federal Government.

That is the same reason that Death Valley National Park is not protesting the appropriation of new water rights for Yucca Mountain, 450 acre feet annually.

However, Death Valley is currently protesting private individuals' transfers of already appropriated water rights that are permitted and in good standing here in Amargosa Valley.

Where is the justice in this?

Response
The National Park Service has been very active in its oversight of water-permit applications and groundwater withdrawals for the Yucca Mountain Site Characterization Project. The Park Service protested the first Yucca Mountain water permit applications, and this resulted in the implementation of a comprehensive groundwater monitoring program in the region. This monitoring program includes Death Valley National Park and Devils Hole Protective Withdrawal. The Park Service routinely receives and analyzes monitoring data from this program to ensure the protection of water resources in the Park.

The National Park Service also submitted comments on the Draft EIS. Its concerns included possible impacts to Death Valley National Park and Devils Hole Protective Withdrawal from the repository.

7.5.3 (2729)
Comment - EIS000709 / 0002
There are two reasons why the Yucca Mountain repository should not be developed: groundwater intrusion and seismic activity. The EIS references the work of "several investigators" who determined the [that] the water table at Yucca Mountain was much higher than it is now, occasionally even reaching the surface. This work was later discredited, but still later, the discreditors were discredited. The DOE says additional research is needed and is ongoing. This proves that the EIS is inadequate; it cannot be considered complete when there is active research into a critical environmental impact.

The information regarding seismic activity is outdated and incomplete. Just since July, there have been two major earthquakes. The EIS says that the repository should be able to withstand a 5.6 magnitude earthquake, yet the seismic potential in the surrounding faults is on the order of 6.5-7.

Response
Based on analyses described in Section 3.1.4.2.2 (Saturated Zone), DOE does not believe a credible rise of the water table could inundate the waste emplacement areas. The EIS discusses evidence that the elevation of water table at Yucca Mountain has fluctuated over time. These fluctuations have been due largely to changes in the climate. DOE examined the cumulative effects on the elevation of the water table from a wetter climate, earthquakes, and a volcanic eruption. Based on the evidence, no reasonable combination of wetter climates, earthquakes, and volcanic eruptions could raise the elevation of the water table sufficiently to inundate the waste-emplacement areas at Yucca Mountain.

Section 3.1.4.2.2 also discusses opposing views on fluctuations in the elevation of the water table. A small number of investigators believe that the water table has risen in the past to elevations higher than the waste-emplacement areas. DOE does not concur with these views, nor did an expert panel that the National Academy of Sciences convened to examine this issue (as described in Section 3.1.4.2.2). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level. Although DOE disagrees with the central scientific conclusions of these opposing views, it continues to support research in this area, and on other aspects of the geology and hydrology to enhance our understanding of the site.

Chapter 5 of the EIS considers the effects of future earthquakes on the long-term performance of the proposed repository at Yucca Mountain. Based on the results of those analyses, DOE believes that a repository would operate safely (in compliance with the public health and environmental radiation protection standards at 40 CFR Part 197). Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes potential impacts from accident scenarios associated with earthquakes during repository operations. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. DOE believes that the EIS adequately describes and analyzes the geology, geologic hazards, and the effects of these hazards on the repository.

Regarding the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 explains how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3 (2919)
Comment - EIS001049 / 0005
Nevada has more than paid its debt by providing security to America, by hosting the Nevada Test Site, and should not have to have further nuclear waste stored in the unproven and earthquake vulnerable Yucca Mountain site. As you know, there has been migration of radioactivity in the ground water toward Death Valley from the Nevada Test Site. There is evidence that the water table has risen in Yucca Mountain and any migration of radioactivity in the water table would endanger Las Vegas, the entertainment capital of the world. The proposed lowered radiation standards wouldn't loosen the risk and are a dishonest attempt to unscientifically present Yucca Mountain as safe.

Response
DOE recognizes that the State of Nevada is home to a number of Federal activities. In particular, the Nellis Air Force Range and the Nevada Test Site occupy large parcels of land in southern Nevada. Sections 8.2 and 8.3.2 of the EIS discuss the short- and long-term cumulative environmental impacts, respectively, posed by these and other Federal actions considered with the Proposed Action. Section 3.1.3.3 discusses modern seismic activity and the seismic hazards associated with the site. That section describes how DOE would construct critical facilities and systems such that they would be able to withstand an earthquake with a return frequency of once in 10,000 years. To support the design of repository facilities, DOE would continue to investigate characteristics of the site and how it would react to an earthquake of such magnitude.

Section 3.1.4.2.2 of the EIS describes the migration of groundwater contamination from the Nevada Test Site (NTS). There is no evidence to indicate NTS activities have contaminated the groundwater beneath Yucca Mountain.

Because groundwater from both Yucca Mountain and the NTS flow toward Amargosa Valley, long-term impacts from NTS activities could be cumulative with those from the Proposed Action (see Section 8.3.2.1).

DOE believes that there is no evidence that groundwater beneath Yucca Mountain would ever rise as high as the level of the proposed repository. As indicated in Section 3.1.4.2.2, DOE believes evidence found during investigations of the site indicates that, during wetter geologic times, groundwater was as much as 120 meters (394 feet) higher than it is today. This is still below the level of the proposed repository emplacement drifts. The same section recognizes that there are viewpoints on the historic groundwater elevations at Yucca Mountain that differ from those supported by DOE. The text summarizes the bases of these opposing viewpoints, the expert reviews established by DOE, and the review results that make DOE believe the opposing viewpoints are based on incorrect interpretations of the data.

Chapter 5 of the EIS discusses the long-term performance of the proposed repository, including potential impacts 10,000 years and more into the future, to people using groundwater that had passed beneath the site. The groundwater flow path is toward Amargosa Valley to the south of the repository site and not, as suggested in the comment, toward Las Vegas, which is to the southeast.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information). The EIS based its analysis of impacts on a state-of-the-art modeling technique that is internationally recognized as an adequate and proper approach. DOE also used this methodology in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998). Chapter 5 of the EIS indicates that impacts would be low and that health effects would be thousands of times less than natural incidences of health problems in the population. The impacts predicted by the analysis would be much lower than the limits established by the Environmental Protection Agency at 40 CFR Part 197. Appendix I of the EIS and supporting documents contain details of the analysis methodology. See Sections 3.1.4.2.1 and 5.4 for additional information.

7.5.3 (3265)
Comment - EIS000602 / 0006
What happens when you get to the dump, to the site? Is the high level of water in the mountain itself going to cause water contamination? That water ultimately essentially gets to the Colorado River and to the city of Las Vegas.

We have been known in this southern part of the state to have flash flooding. Deserts are known to have flash flooding.

Response
As described at the beginning of Section 3.1.4.2.2 of the EIS, the primary emplacement area for the proposed repository is about 300 meters (984 feet) above the present water table. As described in the Saturated Zone discussion of the same section, the DOE investigation of the Yucca Mountain site has shown that during wetter geologic times over the past hundreds of thousands of years, the water table was as much as 120 meters (390 feet) higher than it is today. This is still well below the level of the proposed repository. Section 3.1.4.2.2 also recognizes that there are viewpoints on the historic groundwater elevations at Yucca Mountain that differ from those supported by DOE. The text summarizes the bases of these opposing viewpoints, the expert reviews established by DOE, and the review results that make DOE believe the opposing viewpoints are incorrect interpretations of the data.

Groundwater beneath Yucca Mountain is part of the Death Valley regional groundwater flow system, which, as described in Section 3.1.4 of the EIS, is a terminal hydrologic basin. That is, there is no natural pathway for water (groundwater or surface water) to leave the basin other than by evaporation or transpiration through plants. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, unless it is removed from the system (for example, by pumping, evaporation, or transpiration) before it gets there. The specific flow pattern in this area is from Yucca Mountain south to the Amargosa Desert and then to the primary discharge area of Alkali Flat (Franklin Lake Playa) not toward areas to the north or east. A small fraction of the groundwater may flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains toward spring discharge points in Furnace Creek area of Death Valley. It does not move toward either Las Vegas or the Colorado River drainage system.

Section 3.1.4.1.2 of the EIS addresses the potential for flash flooding events to occur at the site of the proposed repository. Both the U.S. Bureau of Reclamation and the U.S. Geological Survey have generated flood estimates for drainage channels at Yucca Mountain. The location and design of surface facilities that DOE would build in support of the proposed repository would avoid significant impacts from floods. For facilities in which DOE would manage spent nuclear fuel or high-level radioactive waste, this means design against flood levels considered to be the most severe reasonably possible for that site. None of the flood estimates (including those for the regional and probable maximum floods) predicted water levels high enough to reach the entries to the subsurface facilities. In summary, DOE believes flash flooding would not pose a threat to either surface or subsurface facilities associated with the proposed repository.

7.5.3 (3595)
Comment - EIS000715 / 0005
Groundwater upwelling and earthquakes are two issues not adequately discussed in the DEIS. The DOE notes an opposing viewpoint, stating the "Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically higher than 100 meters (330 feet) above the current level, even reaching the land surface in the past (Szymanski, 1989). If such an event occurred, it would affect the performance of the proposed repository" (p. 3-49). DOE even admits, "if such an event occurred, the long-term impacts would probably increase greatly" (p. 5-15). Yet the DEIS dismisses the possibility and does not address the potential impacts of such an event.

DOE notes another opposing viewpoint by Davies and Archambeau which suggests that a moderate earthquake at the site could result in a water table rise of about 150 meters (490 feet) and a severe earthquake could cause a rise of about 240 meters (790 feet) in the water table, which would flood the repository. Nevada ranks third in the nation for current seismic activity. Since 1976, there have been over 600 seismic events of a magnitude greater than 2.5 within a 50-mile radius of Yucca Mountain. The DEIS states that "earthquakes have occurred in the Yucca Mountain geologic region of influence, and are likely to occur in the future" (p. 5-16). Yet, the DOE has repeatedly ignored the potential impacts of future earthquakes at the Yucca Mountain site and refuses to examine how an earthquake might affect the region's groundwater supply.

Response
Section 3.1.4.2.2 of the EIS discusses several opposing views concerning fluctuations in the elevation of the water table at Yucca Mountain. These investigators believe that the water table at Yucca Mountain has risen in the past to elevations that are higher than the subsurface emplacement areas. DOE does not concur with these opposing views, nor did an expert panel that was convened by the National Academy of Sciences to specifically examine this issue [see Section 3.1.4.2.2 of the EIS (Saturated Zone) for details]. DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level. On this basis, DOE did not evaluate the impacts of groundwater inundation of the waste-emplacement areas. This approach is consistent with regulations of the Council on Environmental Quality [40 CFR 1502.1(b)] which state that impacts shall be discussed in proportion to their significance.

Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including seismicity. Section 4.1.8 of the EIS describes the impacts of earthquakes during operation of the repository. Several sections in Chapter 5 consider earthquakes and their effects on the performance of the repository. With the exception of factual changes and clarifications that have been included in the Final EIS, DOE believes that the information on seismic activity in the Draft EIS and the Final EIS adequately describes and analyzes the effects of this activity on the repository.

With regard to the effects of earthquakes on the region's groundwater supply, Section 3.1.4.2.2 of the EIS describes the effects on well-water levels after earthquakes in the region. In brief, water levels have fluctuated by as much as 0.9 meter (3 feet) in response to earthquake events, and confined water pressure deep in wells has fluctuated by as much as 2.2 meters (7 feet) in response to those same events. However, the water levels return to pre-earthquake levels within minutes to hours. An exception was an earthquake in the summer of 1992 that caused water levels in some wells at Yucca Mountain to fluctuate over a few months. Several investigators have speculated that very large fluctuations in water levels can occur during earthquakes. Although the EIS describes these theories in Section 3.1.4.2.2 of the EIS, DOE does not concur with these theories, nor did an expert panel that was convened by the National Academy of Sciences to examine this issue (as described in Section 3.1.4.2.2 of the EIS). In summary, changes to the water table and water supply from earthquakes would not be expected to be large or long-lived.

7.5.3 (3900)
Comment - EIS000654 / 0003
What we do know involves the magnitude earthquakes that have occurred in the region, the fact that it's a seismically highly active region; uncertainties about groundwater movement, but evidence that water has moved within a recent time frame through the rocks surrounding the repository.

Response
DOE recognizes that the effect of earthquakes at the proposed Yucca Mountain Repository is a major concern. The EIS analyzes the probability of occurrence and the potential environmental impacts from earthquakes (Section 4.1.8.1 of the EIS). To support this analysis, DOE and the U.S. Geological Survey completed a comprehensive evaluation of the seismic hazards in the Yucca Mountain region using standard practices of mapping, trenching, age-dating, and monitoring of contemporary seismicity. Then DOE sponsored groups of scientific experts from within and outside the Project used these site data to assess the seismic hazard potential of all significant seismic sources in the Yucca Mountain region. Another group of experts used numerical modeling methods and data from recent earthquakes to estimate ground motion attenuation relationships appropriate for Yucca Mountain.

Using the seismic hazard information described in Section 3.1.3.3 of the EIS, DOE would design repository surface facilities to withstand the effects of earthquakes that could occur during the lifetime of the facilities. The seismic design requirements for the repository specify that the structures, systems, and components important to safety would be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

DOE would build repository subsurface facilities in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have less effect on subsurface facilities than on surface facilities. Inspections of tunnels in the Yucca Mountain area reveal little evidence of disturbance following earthquakes. In addition, DOE would design the subsurface facilities to withstand the effects of earthquakes for the long-term performance of the repository.

The 1992 Little Skull Mountain earthquake was the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain, with a Richter magnitude 5.6. With an epicenter 20 kilometers (12 miles) to the southeast, this earthquake caused no damage at Yucca Mountain. It did cause minor damage to the Yucca Mountain field operations center in Jackass Flat, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), which is an old building that was not built to the seismic design specifications planned for the facilities at Yucca Mountain.

Extensive studies at Yucca Mountain show evidence of low infiltration and percolation rates, long groundwater residence times, and a repository horizon that has been hydrologically stable for long periods (see Section 3.1.4 of the EIS for details). The proposed emplacement areas would be away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release. Any fault movements or displacements from postemplacement seismic activity probably would occur on existing fault planes. Calculations show that there would be almost no effect on repository performance from rockfall.

A fault-fracture dominant flow system is the basis of the hydrology models derived from extensive studies at Yucca Mountain (see Section 3.1.4 of the EIS for details). The addition of new faults by future seismic events would have a very minor or no effect on the current fault and fracture flow pathways and, therefore, would be unlikely to alter repository performance. Long-term performance assessment analyses show that the combination of the natural barriers of the site and engineered barriers would keep radionuclide releases well below the regulatory limits established at 40 CFR Part 197.

7.5.3 (3969)
Comment - EIS001330 / 0001
Yucca Mountain is not a geologically suitable site for nuclear waste disposal. The proposed repository location is in the Basin and Range Province, one of the most geologically active areas in North America. In recent geologic time, the region has experienced episodes of volcanism as evidenced by the layers of volcanic rock and ash that cover the Great Basin and make up Yucca Mountain itself. Some of these volcanic events occurred less than a million years ago. In addition, the region has experienced recent faulting, including some large magnitude earthquakes within the last century. For seismic hazard, Nevada is rated No. 3, indicating a high earthquake risk. There are several faults that are in very close proximity to Yucca Mountain. For obvious reasons, volcanism and faulting pose a serious threat to the stability of a radioactive waste storage site.

Response
Chapter 5 of the EIS considers the effects of future earthquakes on the long-term performance of the proposed repository at Yucca Mountain. Based on the results of those analyses, DOE believes that a repository would operate safely [in compliance with the Environmental Protection Agency's Environmental Radiation Protection Standards at 40 CFR Part 197]. Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes potential impacts from accident scenarios associated with earthquakes during repository operations. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository.

The State of Nevada ranks third, behind Alaska and California, in seismic activity. Its reputation as a highly active state comes primarily from the occurrence of major historical earthquakes (with a magnitude greater than 7 on the Richter scale) in western Nevada. Yucca Mountain is not in this highly active seismic belt. DOE believes that the EIS adequately describes and analyzes the geology, geologic hazards, and the effects of these hazards on the repository. Regarding the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 explains how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3 (3971)
Comment - EIS001541 / 0001
Detailed information regarding climate, geology (more specifically physiography), and hydrology reflective of the Yucca Mountain site 10 to 20 thousand years ago should have been included in the DEIS Chapter 3 discussions on each of these physical characteristics. This recent past climate, physiography, and hydrology information would help put into perspective how these specific characteristics for the Yucca Mountain site have changed over this time period.

There is significant detail as to how the geology developed over the past 10 to 14 million years, but nothing is presented for a past time frame similar to the 10,000-year time period associated with future site performance considerations. It seems rather ironic that no factual details for these parameters over the past 10 to 20 thousand years is presented in this Draft EIS, but theoretical predictions as to how numerous repository characteristics may behave during the coming 10 to 100 thousand years is provided!

Response
DOE believes that the information requested by the commenter is contained in the EIS. The geologic history of the Yucca Mountain area over the past several tens-of-thousands of years is described in Section 3.1.3 (at the end of the subsection titled Site Stratigraphy and Lithology). Briefly, the youngest stratigraphic units at Yucca Mountain consist of unconsolidated boulders, sand, silt, and clay deposited by intermittent streams in and near existing dry washes and in valleys, and unconsolidated and unsorted debris at the base of hillslopes. Spring deposits and windblown sand also occur in the area. For more information about these deposits, see DOE (DIRS 100548-1998). Information on recent faulting and seismicity is contained in Sections 3.1.3.2 and 3.1.3.3. Information on recent past climates and groundwater conditions at Yucca Mountain is in Section 3.1.4.2.2, especially in the subsection titled Saturated Zone.

DOE's assessment of surficial geologic processes during the next 10,000 years is based on the surficial deposits and geomorphic surfaces that developed in the area during Quaternary time (last 1.6 million years). These deposits, and the processes that formed them, are described in CRWMS M&O (DIRS 151945-2000). The Quaternary landscape in the Yucca Mountain area has been dominated by physical weathering, colluvial, eolian, and alluvial processes. These processes have responded to varying climates and climatic changes, as well as to the topography of the mountain and adjacent basins.

The surficial deposits and geomorphic features observed today have developed over the past 10,000 years. The preservation of early and middle Quaternary colluvial deposits on many hillslopes has been cited as evidence of ineffective hillslope erosion during colder, pluvial climates. As an alternative, the amount of time that erosional processes dominate the landscape is less than the time during which hillslopes are mostly stable (DIRS 151945-CRWMS M&O 2000). The absence of alluvial fans along the base of tilted fault blocks is a strong indication of very low rates of tectonic activity. The distribution of Quaternary deposits of different ages in Crater Flat appears to reflect the ongoing opening or extension of the basin.

The map units used to describe the Quaternary rock units at and near Yucca Mountain represent nearly 1 million years of paleoenvironmental history. The landscape has experienced many cycles of Quaternary climatic change, and tectonic activity has continued at a slow, almost imperceptible rate (DIRS 151945-CRWMS M&O 2000). A model of landscape response to climatic change in the southern Great Basin is discussed in CRWMS M&O (DIRS 151945-2000).

Displaced or deformed alluvial and colluvial deposits in the Yucca Mountain area record late Quaternary surface displacement along 11 local faults (DIRS 151945-CRWMS M&O 2000). Prehistoric earthquakes are interpreted based on displacement and timing of surface ruptures at specific locations. A total of 52 exploratory trenches and natural exposures have been excavated, cleaned, and logged in the past 20 years as part of seismotectonic investigations in the Yucca Mountain site area. Twenty-eight trenches at the site display clear evidence for displacement of Quaternary deposits across the fault traces (DIRS 151945-CRWMS M&O 2000). An additional 11 trenches were excavated across the nearby Bare Mountain and Rock Valley faults, located within a 20-kilometer (12-mile) radius of the site. All of these trenches exposed displaced Quaternary deposits (see DIRS 137917-CRWMS M&O 2000). Estimates of timing of surface rupture events form the basis for developing earthquake recurrence models, computing fault-slip rates, and correlating displacements along faults in distributive faulting scenarios. The timing of individual events at a given site is constrained by ages of faulted and unfaulted deposits and soils either exposed in trenches excavated across the fault or located adjacent to the surface trace of the fault.

Geochronologic studies have revealed that deposits and soils exposed in trenches vary in age from late Holocene (1,000 to 2,000 years old) to early Pleistocene (1 million years old). For example, trenches have exposed deposits that are as old as 400,000 years along the Windy Wash and Fatigue Wash faults, up to 750,000 years on the Paintbrush Canyon fault, and more than 900,000 years on the Solitario Canyon fault. Estimated maximum and minimum ages for each faulting event at trench sites are included where age control is available. The Quaternary stratigraphy establishes a record of paleoseismic activity for characterization of the long recurrence, low-slip-rate faults at Yucca Mountain. The resolution and completeness of the paleoseismic record of faulting events decreases with increasing age. In particular, in deposits older than 500,000 years old, fewer events are recognizable and the geologic context of those identified is more poorly understood. This situation is due to incompleteness of older stratigraphic records, deformational overprinting by younger events, and commonly poorer resolution in age control for older deposits. The inventory is most complete and the age data are of highest quality for displacements that occurred within the past 150,000 years. Thus, this time interval is emphasized in developing recurrence models and rupture scenarios (DIRS 151945-CRWMS M&O 2000).

Climate change operates over a wide range of time scales. Geologic-scale climate drivers, such as changing configurations of land masses and oceans due to continental drift, occur over millions of years. Conversely, shorter-term climate drivers, such as the Earth's orbital cycle and solar output cycles, occur over decades to thousands of years. These shorter-term changes have the potential to affect the long-term performance of a repository. Section 6.2 of the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) describes the timing, magnitude, and character of past climate changes in the Yucca Mountain area and establishes the rationale for projecting future changes in the climate. Estimating future hydrologic conditions in the unsaturated zone, saturated zone, and groundwater discharge zone requires an understanding of the timing and types of potential future climates. Wetter and cooler climates that persist for centuries or millennia are of greatest interest, because such climates produce more infiltration, percolation, higher water tables, and more groundwater discharge compared to the present climate.

7.5.3 (4322)
Comment - EIS001222 / 0001
I recommend that this proposal be dropped immediately and permanently for the following reason:

The Yucca Mountain site proposed to hold the nuclear waste is not geologically stable. In 1992 an earthquake of magnitude 5.6 struck within ten miles of the mountain. This suggests that larger quakes are possible in the region. Such larger quakes could damage the containers in which the waste is stored, allowing the waste to leak out and contaminate the surrounding area. Other geological processes known to occur in the vicinity are volcanism and dramatic rises in the level of the water table, either of which can breach container integrity and spread radiation throughout the surrounding area. This is of particular concern because the half-lives of many of the isotopes in the waste are extremely long, in the thousands and millions of years.

Response
Section 3.1.3.1 of the EIS discusses Yucca Mountain as part of a volcanic plateau that formed during explosive silicic eruptions that originated from several calderas north of the site. Over time, this explosive activity began to wane and was replaced by less explosive and much less voluminous basaltic eruptions in the Yucca Mountain region. The last basaltic eruption occurred long ago at Amargosa Valley, about 10 miles south of the site. A panel of outside experts examined the data, models and related uncertainties and concluded that the probability of a volcanic dike disrupting the repository during the first 10,000 years after closure is 1 chance in 7,000 (1 chance in 70 million annually). Section 3.1.3.1 discusses this in more detail. This estimate was recalculated in Section 3.1.3.1

of the Final EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000).

DOE has been monitoring earthquakes in the Nevada Test Site region since 1978. Faults and earthquakes have been investigated as part of the site characterization program to assess seismic hazards at the site. DOE recognizes that the effect of earthquakes on a repository at Yucca Mountain is a major concern and DOE has conducted extensive analyses. The EIS analyzes the probability of earthquake occurrence and the environmental consequences. To support this analysis, DOE and USGS first completed a comprehensive evaluation of the seismic hazards in the Yucca Mountain region using standard practices of mapping, trenching, age dating and monitoring of contemporary seismicity. Then DOE sponsored groups of experts from within and outside the Project used the data to assess the seismic hazard potential of all significant seismic sources in the Yucca Mountain region. Another group of experts used numerical modeling methods and data from recent earthquakes to estimate ground motion attenuation relationships that are appropriate for Yucca Mountain.

Using the seismic hazard information, repository surface facilities would be designed to withstand the effects of earthquakes that might occur during the lifetime of the facilities. The seismic design requirements for the repository specify that structures, systems, and components important to safety must be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

Subsurface facilities would be built in solid rock, and because vibratory ground motion decreases with depth, earthquakes would have less an effect on subsurface facilities than surface facilities. Inspection of existing tunnels in the Yucca Mountain area has revealed little evidence of disturbance following earthquakes. The subsurface facilities would also be designed to withstand the effects of earthquakes for the long-term performance of the repository.

The Little Skull Mountain earthquake of 1992, Richter magnitude 5.6, is the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain. That earthquake, with an epicenter 20 kilometers (12 miles) to the southeast, caused no damage at Yucca Mountain. The event did damage the Yucca Mountain Field Operations Center in Jackass Flats, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), but this facility was not built to the seismic design specifications that are planned for the facilities at Yucca Mountain. Section 3.1.3.3 of the EIS discusses this information in more detail. The results of the probabilistic seismic hazard assessment also indicate that the probability is very small of reactivating faults at the site. Additional fault displacements and associated seismic activity would probably be along existing fault planes.

In addition, the current (flexible) design indicates that waste packages would be placed on pallets in emplacement drifts. Since the waste packages would not be placed in boreholes drilled into the tunnel wall or floor, there is no likelihood that displacement along new faults would shear waste packages. The waste emplacement areas are located in areas away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release. Calculations show that there would be almost no effect on repository performance from rockfall.

Hydrology models, derived from extensive studies conducted at Yucca Mountain, are based on a fault-fracture dominant flow system. The hypothetical generation of a few new faults in the future would have very minor or no effects on the current fault and fracture flow pathways. Potential new faults and fractures, therefore, would not be likely to alter repository performance (see Section 5.7.3 of the EIS).

The repository would be located above the water table in the unsaturated zone. Therefore, the most important process controlling the corrosion of waste packages is whether water would drip from seeps on the waste package. Field and laboratory testing indicate that seepage is expected to be minor and the location of the seeps would depend on fracture-matrix and drift wall interactions. Under the present design, the radioactive waste that is placed in the repository would be enclosed in a two-layer waste package and covered by a titanium drip shield. The waste package would have a chromium-nickel alloy outer layer (Alloy-22) and a stainless-steel inner layer. These materials have extremely low corrosion rates and are not expected to fail for thousands of years.

Investigations by DOE found no evidence or credible mechanism to account for a rise in groundwater to flood the waste-emplacement horizon in the vicinity of Yucca Mountain. Szymanski (DIRS 106963-1989) proposed that during the last 10,000 to 1,000,000 years, hot mineralized groundwater was driven to the surface by earthquakes and volcanic activities. This hypothesis goes on to suggest that similar forces could raise the regional groundwater in the future and inundate the repository horizon.

To investigate this hypothesis further, DOE requested the National Academy of Sciences to conduct an independent evaluation. The Academy concluded that no known mechanism could cause a future inundation of the repository horizon. Scientists working on the Yucca Mountain Site Characterization Project have estimated that the water table could rise by 50 to 130 meters (160 to 430 feet) under an extremely wet climate. Based on geologic evidence, the regional aquifer is estimated to have been as much as 120 meters (390 feet) above the present elevation beneath Yucca Mountain during the past several million or more years. The occurrence of an earthquake under these extreme climatic conditions might cause an additional rise in the water table of less than 20 meters (66 feet), still leaving a safety margin of 20 meters (66 feet) or more between the water table and the waste emplacement horizon. The 1992 Little Skull Mountain earthquake (magnitude 5.6) raised water levels in monitoring wells at Yucca Mountain a maximum of less than 1 meter (3.3 feet) (DIRS 101276-O'Brien 1993). Water levels and fluid pressures in continuously monitored wells rose sharply and then receded over a period of several hours to pre-earthquake levels. The water-level rise in hourly monitored wells was on the order of centimeters and was indistinguishable after 2 hours (DIRS 101276-O'Brien 1993).

Dublyansky (DIRS 104875-1998) proposed another line of data in support of the warm water upwelling hypothesis. That study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. It concluded that some crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of independent experts, including scientists from the U.S. Geological Survey, did not concur with Dublyansky's conclusions. DOE disagrees with the central conclusions in this report, but has supported continuing research by the University of Nevada, Las Vegas. Section 3.1.4.2.2 of the EIS contains more information on groundwater at Yucca Mountain.

Chapter 5 of the EIS describes the components and summarizes the results of DOE's analysis of the long-term performance of the repository (10,000-year regulatory period of 40 CFR Part 197 and for 1 million years). The performance analysis considered the inventory of long-lived radionuclides and their potential pathways to the accessible environment. The results show that the combination of natural and engineered barriers at the site would keep the radionuclides well below the regulatory limits in 40 CFR Part 197.

7.5.3 (4498)
Comment - EIS001434 / 0001
In regard to the Yucca Mountain Draft Environmental Impact Statement (EIS). I take a strong objection as a geologist with 32 years experience that the proposed Yucca Mountain area is a geological stable area.

Swarms of earthquakes are now being reported just North of Beatty. This type of seismic activity is similar to the earthquake activity that was recorded at Mt. Saint Helens before the last volcanic eruption.

The proposed Yucca Mountain Depository is made up of volcanic rocks with cinder cones that have been dated at less than 10,000 years old. It is not a question if there will be additional earthquakes and volcanic activity in the area but when will it occur and to what magnitude.

Construction of a depository that must be stable for 10,000 years or more in a volcanic area is not conceivable.

Response
Based on the results of analyses reported in Chapter 5 of the Draft EIS concerning the long-term performance of the repository, which considered the effects of future seismic and volcanic activity, DOE believes that a repository at Yucca Mountain would operate safely [in compliance with the Environmental Protection Agency's Environmental Radiation Protection Standards at 40 CFR Part 197. Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region.

Section 3.1.3 of the EIS discusses the Lathrop Wells cinder cone which, at between 70,000 and 90,000 years old, is the youngest volcanic center in the region. Section 4.1.8 describes the impacts from accident scenarios associated with earthquakes during operation of the repository. Several sections in Chapter 5 of the Draft EIS consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on geology, geologic hazards, and the effects of these hazards on the repository, have been adequately described and analyzed in the EIS.

Regarding the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 of the EIS explains how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3 (4527)
Comment - EIS001521 / 0040
Page 3-39, fourth paragraph--Define "hydrographic areas." They are not shown on page 3-38, Figure 3-13, and not discussed as hydrologic features.

Response
DOE has changed the terminology for groundwater flow related to region, subregion, basin, and section to be consistent with the source document titled Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California (DIRS 100131-D'Agnese et al. 1997), which is the

main source for this information in Summary Section S.4.1.4 and Section 3.1.4.2.1 of the EIS. The flow in each subregion has clearly defined paths. For convenience, the subregions were divided into basins and sections. The EIS uses these boundaries, which do not define discrete independent flow systems, for descriptive purposes only (DIRS 100131-D'Agnese et al. 1997). The Jackass Flats area is part of the Fortymile Canyon section. The groundwater flow subregion, basin, and section terminology used by D'Agnese et al. (DIRS 100131-1997) is not the same as the terminology used by the State of Nevada for water appropriations (hydrographic areas based on topographic divides); Section 3.1.4.2.1 clarifies that distinction.

7.5.3 (4528)
Comment - EIS001521 / 0041
Page 3-39, fifth paragraph--The "line of springs" location should be shown on page 3-38, Figure 3-13, for clarity. Also, referring to discharge points, a potentiometric-surface map and hydrochemical data as evidence for the springs' locations, while not presenting that evidence, is insufficient. Include the map and examples of the data for clarity and justification of the statement.

Response
Figure 3-15 of the EIS shows the springs mentioned in this comment and are described as being located in Ash Meadows. DOE believes that adding a more detailed depiction of the springs' locations to this figure would be impractical. Also, the line of springs forms much of the western boundary of the Ash Meadows basin, thus a special symbol for the spring line would overlap the boundary shown. A regional potentiometric-surface map is included in this EIS.

It should be recognized that the description in the EIS of the affected environment is a broad summary of the enormous amount of information that has been compiled for the Yucca Mountain site and surrounding areas. The hydrochemical data used to support the conceptualization of groundwater flow patterns in this case is a level of information too detailed for this document. The information under consideration (that is, the general direction of flow through Amargosa Desert and its primary discharge at Alkali Flat) is reported in numerous studies and is not known to be a point of significant contention. The *Yucca Mountain Site Description* (DIRS 137917-CRWMS M&O 2000) provides more information on the Yucca Mountain site and region.

7.5.3 (4602)
Comment - EIS001452 / 0002
The Chemehuevi Tribe feels that the EIS does not sufficiently address the geological stability nor the underground water issue with regards to flow. Lack of scientific and engineering studies and data collection does not warrant this location as a prime area for high-level nuclear disposal.

The EIS does not provide data regarding the underground water flows or drainage towards the Colorado River. As stated in the EIS, "the underground water system is very complex" which indicates that no confirming data to indicate without a doubt that waters do not flow into the Colorado River.

In the event of a major earthquake at Yucca Mountain, there could be the possibility of contamination of the underground water system and the Colorado River, thus contaminating the waters of Havasu Lake and the Chemehuevi Indian Reservation.

Furthermore, attached to this statement is a copy of the Chemehuevi Tribe's Ordinance No. 97.1, PROHIBITING THE DISCHARGE OF ANY POLLUTANT INTO THE WATER OF THE CHEMEHUEVI INDIAN RESERVATION.

Response
DOE has conducted an extensive site characterization program to evaluate the proposed repository at Yucca Mountain, which is in the Death Valley Regional Groundwater Flow System. Death Valley is a closed hydrologic basin, which means that its surface water and groundwater can leave only by evaporation from the soil and transpiration from plants. This area is characterized by a very dry climate, limited surface water, and very deep aquifers. The regional slope of the water table (potentiometric surface) indicates that the groundwater flows south toward Amargosa Valley. The Central Death Valley subregion is comprised of three groundwater basins that are subdivided into smaller sections. Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin, in which

only a small portion of the total basin recharge actually infiltrates through Yucca Mountain. The water that infiltrates the mountain and becomes groundwater recharge then flows toward Fortymile Wash and discharges with the rest of the groundwater in the Fortymile Canyon section of the groundwater basin. Flow continues south toward Amargosa Valley in the Amargosa River section (see Figure 3-15 of the EIS). The natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, more than 60 kilometers (37 miles) away, and not at the Colorado River or Lake Havasu and the Chemehuevi Indian Reservation.

Extensive studies conducted at Yucca Mountain show evidence of low infiltration and percolation rates, long groundwater residence times, and a repository horizon that has been hydrologically stable for long periods. The proposed repository emplacement areas would be in areas away from faults that could affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

7.5.3 (4640)
Comment - EIS001164 / 0001
The local geology is part of a very large context. The context is the intermountain basin and range country which is a very thin part of the earth's crust. Therefore, it is stretching, bulging and subject to fairly massive earth movements, volcanism and earthquakes in the future that are simply unknowable at the present time other than they are more likely here than virtually any other place on the continent except perhaps from right along the Rim of Fire along the Pacific Ocean. But of course, it's the action over there that is driving, actually pulling the crust apart in Nevada, and it's that pulling apart of the crust that is particularly worrisome to me.

Response
DOE shares the commenter's perception that the geology of the site must be understood within the context of the surrounding region. Section 3.1.3 of the EIS discusses both regional and site geology. The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) discusses the regional geologic setting in much greater detail than is appropriate for the EIS. While the basin and range is a product of crustal extension, it is not located along a boundary of one of the tectonic plates that comprise the Earth's crust. Therefore, the tectonic setting of the site is not comparable to locations along the "Ring of Fire" such as California in the vicinity of the San Andreas fault, the Aleutian Islands, or Japan. Section 3.1.3.3 discusses the assessment of potential seismic and volcanic hazards. These assessments are based on both regional and site data and are described in greater detail in Section 12 of the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000).

Section 3.1.3.1 of the EIS discusses Yucca Mountain as part of a volcanic plateau that formed between 14 million and 11.5 million years ago during explosive silicic eruptions that originated from several calderas north of the site. About 11 million years ago, this explosive activity began to wane and was replaced by less explosive and much less voluminous basaltic eruptions in the Yucca Mountain region. The most recent basaltic eruption occurred between 70,000 and 90,000 years ago at Amargosa Valley, about 10 miles south of the site. A panel of outside experts examined the data, models and related uncertainties and concluded that the probability of a volcanic dike disrupting the repository during the first 10,000 years after closure is 1 chance in 7,000 (one chance in 70 million annually). This estimate was recalculated in Section 3.1.3.1 of the Final EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000).

DOE has been monitoring earthquakes in the Nevada Test Site region since 1978. Faults and earthquakes have been investigated as part of the site characterization program to assess seismic hazards at the site. Using the seismic hazard information, repository surface facilities would be designed to withstand the effects of earthquakes that might occur during the lifetime of the facilities. The seismic design requirements for the repository specify that structures, systems, and components important to safety must be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis for

Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

7.5.3 (4702)
Comment - EIS001229 / 0004
The Yucca Mountain site and surrounding area has a history of earthquakes and volcanoes. There have also been major fluctuations in the water table. However, the Department of Energy has ceased consideration of any other geologic repository sites before the Yucca Mountain has been demonstrated to be safe. The Missouri Coalition for the Environment opposes transporting high-level wastes to this unproven and yet-to-be-constructed repository.

Response
Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes potential impacts from accident scenarios associated with earthquakes during repository operations. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository.

Section 3.1.4.2.2 of the EIS discusses evidence that the elevation of the water table at Yucca Mountain has fluctuated over time, due largely to changes in the climate. Based on the evidence, no reasonable combination of wetter climates, earthquakes, and volcanic eruptions could raise the elevation of the water table sufficiently to inundate the waste-emplacement areas at Yucca Mountain. Section 3.1.4.2.2 (Saturated Zone) discusses opposing views on fluctuations in the elevation of the water table. A small number of investigators believe that the water table has risen in the past to elevations higher than the waste-emplacement areas. DOE does not concur with these views, nor did an expert panel that the National Academy of Sciences convened to examine this issue (as described in Section 3.1.4.2.2). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than 120 meters (390 feet) higher than the present level.

7.5.3 (5207)
Comment - EIS001443 / 0031
Groundwater modeling used as the basis for the DEIS does not take into account the potential for accelerated transport of radionuclides due to projected increases in regional groundwater extractions. Growth in Pahrump, the Amargosa Valley, and possible development of pending regional groundwater claims by the City of Las Vegas may lead to significant changes in the direction and volume of groundwater flow from Yucca Mountain. It is well within the ability and purview of DOE to attempt a reasonable projection of the effects of urban development on the regional groundwater system and to incorporate these expectations into the groundwater models utilized in development of the DEIS.

Specific Recommendation: Groundwater modeling conducted in support of the repository site evaluation process should be reworked to incorporate reasonable projections of future regional groundwater usage. The likely effects of regional groundwater development on contaminant plume paths, velocity, and radionuclide concentrations should be projected and mapped.

Response
Predicting trends in long-term future growth is difficult to do with confidence. This was recognized by the National Academy of Sciences, National Research Council, in its advice to the Environmental Protection Agency concerning the development of radiation-protection standards for Yucca Mountain (DIRS 100018-National Research Council 1995). It was the Council's opinion that attempts to predict future human activities and events should not be made because they would likely be more in error than using present-day conditions. In keeping with this recommendation, DOE made no attempt to predict the future course of human activity with respect to how these events could affect the long-term performance of the repository. Nevertheless, some of the uncertainties associated with groundwater flow at and near Yucca Mountain required that the Department incorporate a wide range of flow and transport parameters into the modeling effort. For example, the effective porosity (and, therefore, the resultant flow velocities modeled) for water-bearing strata was sampled from distributions typically ranging over four orders of magnitude (DIRS 101779-DOE 1998). It is reasonable to expect that any changes in aquifer behavior from drawdown due to human development would be small compared to the large variability range modeled, and thereby incorporated within the statistical range reported. In addition, with respect to the long-term performance of the repository,

simulated changes in the climate (ranging from very wet to very dry climates) easily captured the effects of any changes to the hydrologic setting caused by human activities.

7.5.3 (5491)
Comment - EIS001887 / 0159
Page 3-29 to 30; Section 3.1.3.3 - Modern Seismic Activity - Seismic Hazard

The Final EIS should include the updated results of Dr. Wernicke's research relative to tectonic deformation and make any necessary adjustments in seismic and volcanic risk estimates.

Response
DOE is continuing to fund additional investigations on the regional crustal strain rate in the Yucca Mountain region as specified in a cooperative agreement with the University of Nevada. Dr. Wernicke, the principal investigator of one study, recently estimated in a quarterly report to the DOE that conclusions from this study would be available in 2002. This study involves 30 geodetic monument sites with continuous Global Positioning System measurements, a significant improvement over the previous study mentioned in the comment. The Final EIS incorporates the best available information.

7.5.3 (5596)
Comment - EIS001887 / 0222
Page 4-18; Section 4.1.3 - Impacts to Hydrology

The Draft EIS should give a map delineating the "region of influence." Is this region the same as the proposed 150,000 acres withdrawal area?

Response
Section 4.1.3 of the EIS describes the regions of influence for both surface water and groundwater. In neither case are the regions of influence limited to the proposed 150,000-acre withdrawal area nor can they be represented by firm boundaries on a map. Potential impacts to surface water includes not only runoff channels that could be disturbed by or receive direct runoff from proposed activities at Yucca Mountain, but downstream collection channels as well. With respect to groundwater, the region of influence encompasses those aquifers beneath Yucca Mountain and downgradient aquifers to which they contribute water.

Chapter 3 of the EIS contains descriptions and maps of the affected environment to better understand the regions of influence described in Chapter 4.

7.5.3 (5597)
Comment - EIS001887 / 0223
Page 4-19; Section 4.1.3 - Impacts to Hydrology

Define and quantify "minor changes," "minor impacts," "extremely small," and "very low."

Response
The first three phrases in the comment ("minor changes," "minor impacts," and "extremely small") are associated with summary statements that describe conclusions reached through analyses presented later in the text. Those later discussions provide an understanding of what each phrase means. Some of the conclusions reached in the discussions are based on qualitative analyses, with no attempt to associate a value or quantity with the conclusion. The use of "very low" in the second paragraph in Section 4.1.3.1 to describe the potential for groundwater contamination during preconstruction testing and performance confirmation studies is such a case. In this section and in general throughout the EIS where qualitative analyses lead to a description of impacts using terms such as "minor" or "extremely small," DOE feels that the topic is not a major issue and that the associated discussion should lead the reader to the same conclusion. DOE believes this approach is consistent with Council on Environmental Quality regulations that state [40 CFR 1502.2(b)], "Impacts shall be discussed in proportion to their significance. There shall be only brief discussion of other than significant issues. As in a finding of no significant impact, there should be only enough discussion to show why more study is not warranted."

7.5.3 (6348)
Comment - EIS001793 / 0003
Both DOE and many other scientists find many problems with this whole process. There is extensive geological data, as many people have mentioned, on Yucca Mountain. The area could not possibly keep the waste isolated. It is highly seismologically active, it contains many past volcanoes and possible magma pockets now. It has highly fractured rock and will allow flow of water and radioactive materials to occur.

Response
Based on the results of analyses on the long-term performance of the repository (Chapter 5 of the EIS), which considered the effects of future seismic and volcanic activity, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with the Environmental Protection Agency's Environmental Radiation Protection Standards at 40 CFR Part 197). Section 3.1.3 of the Draft EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Regarding a possible magma pocket beneath Yucca Mountain, Biasi (DIRS 105358-1996) demonstrated rather conclusively that there is no low-velocity zone (a geophysical anomaly that could indicate a magma pocket) under either Crater Flat or Yucca Mountain that would suggest a major volcanic hazard. Section 4.1.8 of the EIS describes the impacts from earthquakes during operation of the proposed repository. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on geology, geologic hazards, and the effects of these hazards on the proposed repository, have been adequately described and analyzed in the EIS.

Regarding the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 of the Draft EIS explains how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3 (6427)
Comment - EIS001632 / 0012
Second, this paragraph [p. 2-37, Section 2.1.2.3] states, "Provisions could be added for post-closure monitoring." The EIS should elaborate on when and how DOE would add post-closure monitoring.

Response
DOE would design and implement a postclosure monitoring program in compliance with the Nuclear Regulatory Commission regulations (10 CFR Part 63). Before closure, DOE would submit an application for a license amendment to the Commission for review and approval. The application would include, among other items:

1. An update of the assessment of the performance of the repository for the period after closure

2. A description of the postclosure monitoring program

3. A detailed description of measures to regulate or prevent activities that could impair the long-term isolation of the waste, and to preserve relevant information for use by future generations

The application also would describe DOE's proposal for continued oversight to prevent any activity at the site that would pose an unreasonable risk of breaching the repository's engineered barriers, or increase the exposure of individual members of the public to radiation beyond limits allowed by the Nuclear Regulatory Commission. DOE has modified Chapter 9 of the EIS to include the types of monitoring and other institutional controls that would be contemplated. The Department would develop the details of this program during the consideration of the license amendment for closure. This would allow the Department to take advantage of new technological information, as appropriate.

7.5.3 (6506)
Comment - EIS001813 / 0001
Groundwater upwelling and earthquakes are two issues not adequately addressed in the DEIS. DOE does not address the potential impact of dramatically higher water table levels than currently exist even though their own studies provide evidence that suggests this is an actual possibility. The DEIS states that "earthquakes have occurred in the Yucca Mountain geologic region of influence and are likely to occur in the future." Yet the DOE has repeatedly ignored the potential impacts of future earthquakes at the Yucca Mountain site and refuses to examine how an earthquake might affect the region's groundwater supply.

Response
Section 3.1.4.2.2 of the EIS discusses several opposing views concerning fluctuations in the elevation of the water table at Yucca Mountain. These investigators believe that the water table at Yucca Mountain has risen in the past to elevations that are higher than the subsurface waste-emplacement areas. DOE does not concur with these opposing views, nor did an expert panel that was convened by the National Academy of Sciences to specifically examine this issue (see Section 3.1.4.2.2 of the EIS for details). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level.

Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including seismicity. Section 4.1.8 of the EIS describes the impacts of earthquakes during operation of the repository. Several sections in Chapter 5 consider earthquakes and their effects on the performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on seismic activity, and the effects of this activity on the repository is adequately described and analyzed.

With regard to the effects of earthquakes on the region's groundwater supply, Section 3.1.4.2.2 describes the effects on well-water levels after earthquakes. In brief, water levels have fluctuated by as much as 0.9 meter (3 feet) in response to earthquake events, and confined water pressure deep in wells has fluctuated by as much as 2.2 meters (7 feet) in response to those same events. However, the water levels return to pre-earthquake levels within minutes to hours. An exception was an earthquake in the summer of 1992 that caused water levels in some wells at Yucca Mountain to fluctuate over a few months. Some investigators have speculated that earthquakes can cause very large fluctuations in water levels. Although these opposing views are described in Section 3.1.4.2.2, DOE does not concur with these views, nor did an expert panel that was convened by the National Academy of Sciences to specifically examine this issue. In summary, fluctuations in the elevation of the water table and changes in the water supply from earthquakes would be neither large nor long-lived.

7.5.3 (6648)
Comment - 010402 / 0002
Directly associated with the issue of geologic stability is the fact that radioactive water was found to be leaking into the excavated test tunnel area. The presence of radionuclides from nuclear testing found in the water are a clear indicator that this water made its way from surface origins to deep in Yucca Mountain in less than 50 years. Moisture from any source will speed the decomposition of the casks holding the irradiated fuel. The earlier that the integrity of the casks are breach [breached], will allow for higher the levels of radiation leakage into the surrounding environment. It should be noted that no matter how the casks are constructed, they would not last as long as the radioactive life of the waste inside.

All radiation leaks from this deadly waste will endanger the aquifer under Yucca Mountain. This aquifer is the major water source for the farmers, ranchers, and citizens of Amargosa Valley, Beatty and Oasis Valley. In a desert environment lacking other water sources, it is foolhardy and reckless to say the least to risk contamination of this aquifer.

Response
As described in Section 3.1.4.2.2 of the EIS, DOE has used the isotope chlorine-36 to investigate the nature of water infiltration and deep percolation at Yucca Mountain. These investigations have detected elevated amounts of "bomb-pulse" chlorine-36 from atmospheric testing of nuclear weapons during the 1950s and 1960s. The bomb-pulse chlorine-36 in the subsurface at Yucca Mountain is generally associated with faults and well-developed fracture systems close to these faults. The elevated amounts of chlorine-36 could be evidence of a connected pathway through which surface precipitation has percolated to depth within the last 50 years.

DOE believes that these findings do not indicate that the Yucca Mountain site would be unsuitable for development as a repository. Most of the water that infiltrates through Yucca Mountain moves slowly through the matrix and fracture network of the rock. Isotopic data from water extracted from the rock matrix indicate that the residence time of groundwater might be as long as 10,000 years. Furthermore, after excavating more than 11 kilometers (8.4 miles) of tunnels at Yucca Mountain, DOE found that only one fracture was moist (there was no active flow of water). This observation has been confirmed in test alcoves that are not subject to the effects of drying from active ventilation.

To ensure the correct interpretation of this chemical signal, DOE instituted additional studies to determine if independent laboratories and related isotopic studies can corroborate the detection of elevated concentrations of chlorine-36. Results of the validation studies to this point have not allowed firm conclusions and, thus, the evaluations continue. Nevertheless, the results of the Total System Performance Assessment described in Chapter 5 of the EIS incorporate the fast-flow data. The results show that the combination of natural and engineered barriers at Yucca Mountain would keep releases of contaminants during the first 10,000 years after closure well below the radiation limits established in 40 CFR Part 197.

Another important factor concerning the safety of the emplaced waste is whether percolating water would actually contact the waste packages. The process of drift excavation creates a capillary barrier that would cause the diversion of percolating water around the drift opening, further reducing the amount of water potentially capable of contacting waste packages. DOE is conducting experiments to determine the seepage threshold, which is the amount of water necessary to overcome the capillary barrier caused by excavation. Results to date suggest that the amounts of percolating water at the waste-emplacement level could be insufficient to exceed the existing capillary barrier. To increase the confidence in the safe, long-term performance of the repository, the Department would include titanium drip shields to cover the waste packages and divert any water that might infiltrate to these depths away from the waste packages. This design is described in Chapter 2 of the EIS.

7.5.3 (6957)
Comment - EIS001251 / 0001
There are physical limitations within Yucca Mountain that make it unsuitable for long-term geologic storage of radioactive waste materials.

I'm sure you are aware of the strain rates on Yucca Mountain measured by the team of Caltech and Harvard seismologists using DGPS (Wernicke et al., Science 279, 27-Mar-98, pp. 2096-2100). These measurements corroborate other triangulation records and demonstrate a strain rate "about three to four times the average Basin and Range rate." The authors believe that this strain rate will result in volcanic activity across Yucca Mountain, the Lathrop Wells cone already being the first. I see no accounting of this seismological evidence in the DEIS. I want to see this matter, the strain rate, and possible volcanic activity during the expected life of the waste site, fully explored and discussed openly.

Another matter of utmost concern is the presence of "bomb-pulse" Cl-36 and Tc-99 in rocks taken from three fracture zones (and perhaps three others) in the Exploratory Studies Facility, demonstrating fast flow in Yucca Mountain (Fabryka-Martin, et al. LA-13352-MS, UC-802, December 1997). The high strain rate (see above) will probably increase the number of fracture zones. Fast flow within the mountain requires that, once a canister corrodes, its contents will flow quickly into the environment. Surely the danger to living systems needs no further emphasis.

It is very important that the physical limitations of the Yucca Mountain site be recognized. If we are truly putting the huge quantities of radioactive wastes away for all time, and not merely responding to political expediency, then we must give grave attention to Yucca Mountain's flow patterns and instabilities. Please inform me of any action you take on these matters.

Response
As reported in Section 3.1.3.3 of the EIS, Wernicke et al. (DIRS 103485-1998) claims that the crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than the tectonic history of the area would predict. This study speculates that higher strain rates would indicate underestimation of potential volcanic and seismic hazards on the basis of the long-term geologic record. In May 1998, U.S. Geological Survey scientists reassessed seismic strain rates (DIRS 118952-Savage, Svarc, and Prescott 1999). The principal strain rates determined during the 1983-to-1998 survey confirmed previous analyses and were significantly less than those reported by Wernicke et al. (DIRS 103485-1998). The Survey scientists concluded that the residual strain rate in the Yucca Mountain area is not significant at the 95-percent confidence level after removal of effects of the 1992 Little Skull Mountain earthquake and the strain accumulation on faults in Death Valley.

DOE is continuing to fund additional investigations on the regional crustal strain rate in the Yucca Mountain region as specified in a cooperative agreement with the University of Nevada. Dr. Wernicke, the principal investigator of one study, recently estimated in a quarterly report to DOE that conclusions from this study would be available in 2002. The Department would report conclusions as they became available. If the higher crustal strain rates were confirmed, DOE would reassess the volcanic and seismic hazard at Yucca Mountain.

The hydrologic model of Yucca Mountain is a fault-fracture flow system. The hypothetical addition of a few new faults and associated seismic events would have negligible effects on the current fault- and fracture-flow pathways. Potential new faults and fractures, therefore, would be unlikely to alter repository performance. However, if there was confirmation of higher crustal strain rates, DOE would reassess the effect on radionuclide transport and total system performance.

Yucca Mountain is part of a volcanic plateau that formed between 14 million and 11.5 million years ago during explosive silicic eruptions that originated from several calderas north of the site. About 11 million years ago, this explosive activity began to wane and was replaced by less explosive and much less voluminous basaltic eruptions in the Yucca Mountain region. The most recent basaltic eruption occurred between 70,000 and 90,000 years ago at Amargosa Valley, about 16 kilometers (10 miles) south of the site. A panel of outside experts examined the data, models and related uncertainties and concluded that the probability of a volcanic dike disrupting the repository during the first 10,000 years after closure is 1 chance in 7,000 (1 chance in 70 million annually). The estimate was recalculated in Section 3.1.3.1 of the EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000).

7.5.3 (7081)
Comment - EIS001847 / 0013
Why will Yucca Mountain fail to isolate nuclear waste? Why is it fractured? The answer is very simple. This area is as seismically active as the California Bay Area. There have been more than 600 earthquakes within a 50-mile radius of the site within the last 20 years. A major jolt knocked windows out of a DOE facility in the early 1990's. In 1998 and 1999 there have been a whole spate of tremblers, at greater frequencies than previously observed.

All this shaking has fractured the relatively soft rock (tuff) that forms this low snaking ridge. There are 35 active fault lines in the area, including two that traverse the repository site itself, but the entire mass of Yucca is a sieve with tiny fractures that allow water and gas to flow.

A striking feature of the Yucca landscape is a line of lava cones that extends to the west of the Mountain. The youngest cone is closest to Yucca Mountain. This is clear evidence of the possibility of a magma pocket, which the earth's crust is moving slowly across. Like the formation of the Hawaiian Islands, these lava cones are like the squirts from a subterranean pastry bag.

Further evidence supporting the presence of a magma pocket comes from research published in Science magazine under contract with the U.S. Nuclear Regulatory Commission. The use of global positioning satellites allows tracking of the movement of Earth's crust. The crust at Yucca is expanding. It is also moving westward at an accelerating rate. The authors conclude that this evidence is "consistent with" the presence of a magma pocket under Yucca Mountain.

The Western Shoshone People who have rightful claim to the land at Yucca Mountain have a different name for this site. It translates: "Serpent Swimming West." If we would listen to ancient wisdom, and pay attention to the earthquakes, we might be able to avert a major environmental catastrophe of burying nuclear waste where it will almost certainly leak.

Response
Based on the results of analyses reported in Chapter 5 of the EIS concerning the long-term performance of the repository, which considered the effects of future seismic and volcanic activity, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with the Environmental Protection Agency's Environmental Radiation Protection Standards at 40 CFR Part 197). Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region.

The geodetic study reported in the March 1998 issue of *Science* (DIRS 103485-Wernicke et al. 1998) was based on baseline measurements using the Global Positioning System over the period 1991 through 1997 at five stations in the Yucca Mountain area. (This topic is discussed in Section 3.1.3.3 of the EIS.) While the authors of that study discussed the possible effects on their network from displacements associated with the June 1992 Little Skull Mountain earthquake, they did not correct the station-to-station distances for earthquake displacements.

In May 1998, scientists from the U.S. Geological Survey resurveyed a network of 14 geodetic stations that was originally installed in 1983. Two of the 14 stations were used by Wernicke et al. (DIRS 103485-1998) in their study. Based on the greater number of stations, the longer survey period (1983 through 1998), and the removal of the effects of the June 1992 Little Skull Mountain earthquake, the U.S. Geological Survey scientists concluded that the strain rate in the Yucca Mountain region is significantly less (a factor of 20 or more) than the rate reported by Wernicke et al. (DIRS 103485-1998). These results are consistent with a large body of geological and paleoseimological data that have been collected in the Yucca Mountain region during the past two decades.

Wernicke et al. (DIRS 103485-1998) speculated that the high strain accumulation across the Yucca Mountain area could be caused by magmatic inflation at depth. They pointed to an early seismic study by Oliver, Ponce, and Hunter (DIRS 106447-1995) that hinted at the presence of a low-velocity zone beneath Crater Flat that could be consistent with basaltic magma. A subsequent study by Biasi (DIRS 105358-1996) demonstrated rather conclusively that there is no low-velocity zone (for example, magma pocket) under either Crater Flat or Yucca Mountain that would suggest a major volcanic hazard.

Section 4.1.8 of the EIS describes the impacts from earthquakes during operation of the proposed repository. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on geology, geologic hazards, and the effects of these hazards on the repository, have been adequately described and analyzed in the EIS.

Regarding the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 of the Draft EIS explains how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3 (7199)
<u>Comment</u> - 010162 / 0001
Granite is porous. And as a result, and I hear our friend and welcome him from Wisconsin, talking about granite. All of these rocks are porous, and they will eventually dissolve either through microbic invasion, those are my bugs, or through natural erosion and whathaveyou.

<u>Response</u>
The rock at and below Yucca Mountain is, for the most part, composed of many thousands of feet of various types of volcanic flows that are millions of years old. Below these volcanic layers are many thousands of feet of older sedimentary rock. Sections 3.1.3 and 3.1.4 of the EIS describe the geologic and hydrologic settings of Yucca Mountain and the surrounding region in great detail. Based on the results of modeling of the long-term performance of the repository (see Chapter 5 of the EIS), which considered surface precipitation reaching the underground repository within decades and possible microbial degradation, DOE believes that the repository would operate safely; that is, it would be in compliance with the radiation-protection standards developed by the Environmental Protection Agency for the Yucca Mountain site (10 CFR Part 197).

7.5.3 (7387)
<u>Comment</u> - EIS001957 / 0014
No mention is made in the draft EIS of studies that have been conducted that have simulated the effects of potential increased infiltration at the proposed site (due to a wetter climate). One such study, for example, was published in the Journal of Ground Water of the Association of Ground Water Scientists & Engineers, July-August 1999, entitled Numerical Modeling of Perched Water Under Yucca Mountain, Nevada, by J.J. Hinds (of Lawrence Berkeley National Laboratory) and others. Significant excerpts are as follows:

"These perched water bodies are believed to have important implications for ground water travel times and flow pathways, and for radionuclide transport through the unsaturated zone. Perched water could potentially increase corrosion rates of engineered waste canisters and shorten ground water travel times, leading to more rapid and focused dispersal of radionuclides to the environment. Consequently, a thorough understanding of perched water dynamics is necessary for site evaluation."

"To investigate the effect of a wetter climate on the unsaturated flow regime, we use the approximate steady-state results from the base-case scenario as our initial conditions and increase the infiltration rates by a factor of five ...a simulation time of 10,000 years is used, since it represents the period of time over which the waste should remain isolated."

The article goes on to state effect of higher infiltration rates on the perched water system is substantial:

"The simulations presented in this study illustrate how contrasts in...climate...can affect moisture distribution and flow within the unsaturated zone and, particularly, the perched water system under Yucca Mountain. The persistence of perched water has important implications for waste isolation. The migration of radionuclides away from a potential repository may accumulate in perched water bodies and may become focused along structural pathways, like faults, that cut through the major hydrogeologic units and provide a direct link to the water table, allowing flow to bypass sorptive zeolites. The simulations presented here illustrate that moisture, accumulating at lithologic boundaries to form perched water, may drain to the water table along fault zones. Additional results show that the size of perched water at Yucca Mountain is sensitive to changes in climate. The introduction of more moisture into the subsurface by increasing infiltration leads to shorter ground water travel times and growth of perched water bodies..."

We contend based upon this material that the draft EIS is inadequate in assessing effects of possible climate changes over the next 10,000 years on the likelihood of transport of radionuclides from the proposed repository to the water table, and the regional ground-water flow systems, which discharge at Death Valley [NP] National Park.

Response
Section 3.1.4.2.2 of the EIS describes the occurrence of perched water below the proposed repository. The presence of perched water above the regional water table is a positive factor in relation to the potential transport of radionuclides from the repository for the following reasons:

1. The fact that water is perched between the repository horizon and the water table indicates a barrier to flow. In this case, the perching layer possesses less matrix permeability and has a smaller fracture density than the overlying rocks.

2. The age of the perched water is thousands of years. The perching layer appears to impede the downward flow of water so that the water has aged substantially (thousands of years) in its current location. This increased residence time affords greater opportunity for diffusion and sorption of radionuclides that are potentially released from a breached repository.

While the studies mentioned in the comment are not directly mentioned in the EIS, these studies were an integral part of the development of the Total System Performance Assessment. Perched water bodies, wetter climates, and related conditions (as mentioned in the comment) are incorporated directly into the calculations to estimate long-term performance of the repository. The higher infiltration rate mentioned is equivalent to the superpluvial climate included in the modeling. In the model, the faster flowpaths and the shorter travel distances occur during wetter climatic conditions.

7.5.3 (7457)
Comment - EIS001969 / 0011
Page S-36, 5.4.1.3 [S.4.1.3] Geology, second paragraph.

The correct name of the repository host rock is the Topopah Spring Tuff, not "Topopah Springs Formation" or "Topopah Springs formation."

Response
DOE has corrected the name of the repository host rock to "Topopah Spring Tuff."

7.5.3 (7469)
Comment - EIS001969 / 0015
Page 3-16, Site Stratigraphy and Lithology.

The sedimentary history of the region including the Tertiary sedimentary rocks (for example Pavits Springs Formation) need to be discussed in this section and included in Table 3-6 (page 3-19).

Response
Although the EIS is concerned with the sedimentary history of the region and sedimentary rock units at Yucca Mountain, the main focus is on those units important for the study of groundwater infiltration, flow, and transport. Table 3-6 is highly generalized and identifies only the Topopah Spring Tuff, the repository host rock, by name. The commenter is referred to other parts of Section 3.1.3 of the EIS that describe the history and stratigraphy of the Yucca Mountain area, and to Table 3-7, which describes the Tertiary rock units at Yucca Mountain in more detail than Table 3-6.

7.5.3 (7506)
Comment - EIS001969 / 0017
Page 3-19, first paragraph.

The "pre-Cenozoic" (see above) rocks are also exposed at Calico Hills and Striped Hills, which are as close or closer to Yucca Mountain than are the pre-Cenozoic rocks at Bare Mountain, and therefore should be included in the discussion.

For clarity, the borehole (first paragraph) should be described as 2 kilometers east of the crest of Yucca Mountain, because Yucca Mountain is physiographically defined as all the numerous ridges that surround the borehole.

Response
This comment is correct. DOE has revised Section 3.1.3.1 of the EIS to include the exposures at Calico Hills and Striped Hills.

7.5.3 (7514)
Comment - EIS001969 / 0022
Page 3-25, Section 3.1.3.2 Geologic Structure.

Discussion of the occurrence of joints and fractures in the volcanic rock at Yucca Mountain is needed in this section, including mention of the geographic and stratigraphic distribution of fractures, and whether they are fault- and/or stratigraphically-controlled.

Response
DOE has modified the discussion in Section 3.1.3.2 of the EIS. The faults described are well-defined structures; joints, along which there is no appreciable movement, also occur in the rock units mapped at the site. Within the Paintbrush Group (Tiva Canyon, Yucca Mountain, Pah Canyon, and Topopah Spring tuffs), joints have been subdivided into three groups based on how they developed and their approximate time of origin: early cooling joints, later tectonic joints, and joints due to erosional unloading (DIRS 151945-CRWMS M&O 2000). Each group of joints exhibits specific characteristics with respect to joint length, orientation, and connectivity. The cooling and tectonic joints have similar orientations (generally trending north-south), whereas cooling joints include irregularly spaced horizontal joints as well. Joints that developed from erosional unloading are variably oriented but trend predominantly east to west, perpendicular to the cooling and tectonic joints. Tectonic joints occur throughout the Paintbrush Group; cooling joints occur in each of the welded units. In general, the Tiva Canyon tuff and the Topopah Spring tuff have the highest joint frequencies and joint connectivities. The nonwelded Yucca Mountain tuff and the Pah Canyon tuff have the fewest joints. Geologic, geoengineering, and hydrologic aspects of fractures are discussed in detail in the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000). DOE has added to Section 3.1.3.2 of the EIS more information about joints and fractures in the volcanic rock at Yucca Mountain.

7.5.3 (7517)
Comment - EIS001969 / 0023
Page 3-25, Section 3.1.3.2 Geologic Structure, second paragraph.

"Major crustal compression" and "crustal extension" need to have an associated direction, such as "Major east-west crustal compression" and "east-west crustal extension."

Crustal compression is stated to have occurred between 350 and 50 Ma [million years ago], but there is no evidence for east-west compression younger than about 100 Ma in this region.

Response
The text in Section 3.1.3.2 has been modified to indicate that major east-west crustal compression occurred periodically in the Great Basin between about 350 million years ago to about 65 million years ago. This compression moved large sheets of older rock great distances upward and eastward over younger rocks to produce mountains. References to support this discussion include Armstrong (DIRS 101583-1968), Fleck (DIRS 150625-1970), CRWMS M&O (DIRS 100127-1998), and Dunne (DIRS 102861-1986).

7.5.3 (7859)
Comment - EIS001653 / 0039
The groundwater section [3.1.4.2] also needs a thorough discussion of groundwater users in the region of influence including the type and amount of use. Future water demands estimates should be described with low, medium and high growth scenarios and not assume that the population does not grow. The DEIS concludes that Amargosa Valley area population in 10,000 years will be the same as in 1990.

Response
According to Council on Environmental Quality regulations (40 CFR 1502.15), descriptions of the environment potentially affected by a proposed action or its alternatives shall be no longer than is necessary to understand the effects of the alternatives. DOE understands that people with a particular interest in water might wish to see more detail, but believes that Section 3.1.4.2.1 of the EIS, and particularly Table 3-11, provide an adequate summary of water use in the region of influence.

Sections 4.1.3.3 and 4.1.11.2 of the EIS address projected water demands attributed to the construction and operation of the proposed repository and due to population growth as a result of the Proposed Action, respectively. Both sections evaluate impacts of the Proposed Action's water needs primarily by comparing them to current water demands. This is a conservative evaluation because the relative impact would only decrease as population grew and water demand associated with the Proposed Action became an even smaller portion on a percentage basis.

DOE assumes that the comment's reference to the use of current population numbers in 10,000 years is directed toward the long-term performance assessment discussed in Chapter 5 of the EIS. DOE did base population consequences for the 10,000-year evaluation on current population numbers. As described in Section 5.2.4.1 of the Draft EIS, DOE's use of current population numbers was in accordance with guidance provided by the National Research Council of the National Academy of Sciences. The guidance states that due to the difficulty of long-term population projection, calculations of population dose should use present population numbers.

DOE recognizes the potential for disagreement with the long-term population assumptions presented in Chapter 5, but does not have a basis on which to predict long-term population changes quantitatively and, therefore, chose to follow National Academy of Sciences guidance rather than perform such a speculative analysis. In addition, DOE notes that the evaluation does not take credit for future technologies that could improve the ability to remove radioactive materials from drinking water or the environment or for medical advances that could involve cures for cancer.

DOE has revised Chapter 5 of the EIS extensively to address the results of updated analyses. The updates cover new data collected from ongoing investigations and changes in the repository design. DOE has modified Chapter 5 analyses to conform to new standards promulgated by the Environmental Protection Agency and Nuclear Regulatory Commission as published in 40 CFR Part 197 and 10 CFR Part 63, respectively. These standards will be used to judge the performance of the repository as part of the licensing process. Chapter 5 now addresses exposure scenarios set by these standards, which define a hypothetical reasonably maximally exposed individual and a groundwater protection standard set for a hypothetical community. The hypothetical community has a defined population and location with respect to its distance along the groundwater flow path from Yucca Mountain.

7.5.3 (7956)
Comment - EIS001933 / 0001
You know that Yucca Mountain is not a mountain at all but just a ridge and that it's white band is a result of sudden shifting.

Response
DOE agrees that, as a landform, Yucca Mountain is a ridge. The Department is not clear, however, what the commenter means with regard to "a white band is a result of sudden shifting." The exposed rocks at Yucca Mountain are shades of brown and gray.

7.5.3 (8436)
Comment - 010242 / 0019
Page 2-20: Figure 2-7 - Proposed Action repository layouts for the Draft EIS high, intermediate, and low thermal load scenarios, and the S&ER flexible design operating mode.

The S&ER flexible design operating mode repository layout includes possible extensions of the repository into areas that have not been characterized with the benefit of the Exploratory Studies Facility and the cross drift. The northern extension would bring the waste emplacement area closer to the area known as the large hydrologic gradient, for which a satisfactory explanation of its origin has not been determined (and apparently is not intended to be). The southern extension area has not been investigated for the possibility of its being transected by another

NW-SE fault similar to the Sundance Fault. Also, rock characteristics, thickness of formations, and fault offset are known to vary from north to south at Yucca Mountain, all of which require detailed investigation before being included in the models used for performance assessment. Additional data, information, and analysis is needed before the S&ER flexible design repository layout is acceptable for inclusion in the Supplement.

Response

Figure 2-7 in the Supplement to the Draft EIS shows the maximum emplacement drift area that would be required for any of the various flexible-design operating modes being considered under the proposed action. Both drift areas shown in the figure for the flexible design are slightly larger than corresponding areas shown for the repository layouts described in the Draft EIS (and also shown in Figure 2-7). The only situations that would possibly require the repository to move into areas beyond the primary and lower block are associated with the Inventory Module 1 and 2 inventories described in Chapter 8 of the EIS. Section 8.1.2.1 describes the potential for the repository to accept the additional Inventory Module 1 and 2 waste as a reasonably foreseeable future action. However, these inventories could not be emplaced in Yucca Mountain without legislative action, because the repository limit is established at 70,000 MTHM. Also described in Section 8.1.2.1, should geologic blocks be needed beyond those supporting the Proposed Action, they would be characterized more fully before their use.

Potential repository areas outside the primary area have been designated (should they be needed). Although these areas have not been characterized to the extent of the primary block, they are not uncharacterized. Many of the studies and evaluations performed during site characterization have included a much broader area than what might be used for the repository. For example, faults within 100 kilometers (62 miles) of Yucca Mountain have been examined using aerial photographs. All with suspected Quaternary movement were evaluated; and the evaluations to estimate the probability of volcanic activity at Yucca Mountain looked at evidence of regional activity.

The comment is correct in noting that the flexible design layout extends farther north than the layouts described in the Draft EIS, and that this is the area of the steep hydraulic gradient, where the groundwater would be closest to the repository level. With respect to further study of this phenomenon, DOE has not said it would perform no further investigations, but that such investigations would have a lower priority than work considered to be critical. This is because DOE believes, based on expert opinions on this topic, that whatever the specific cause of this steep hydraulic gradient, there is no reason to believe that it could adversely affect the proposed repository.

With respect to depth to groundwater, the distance from the level of the repository to the water table has been adjusted slightly in the Final EIS to account for new data and the small change in repository layout. As noted in Section 3.1.4.2.2 of the EIS, the repository block would be at least 160 and as much as 400 meters (520 up to 1,300 feet) above the present water table. [The depth range described in the Draft EIS was 175 to 365 meters (570 to 1,200 feet)]. These are conservative estimates of the depth from the repository to the water table that come from the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000). A more recent document, the *Yucca Mountain Science and Engineering Report* (DIRS 153849-DOE 2001, Figure 1-13), presents a similar repository layout figure for the flexible design, but the figure is superimposed with groundwater elevation contours. In that figure, and as described in associated text, the depth from the primary block's northern most emplacement drift to the groundwater is about 210 meters (690 feet). The north main access drift loops a little further to the north where groundwater would be higher, but it would not be a location of waste emplacement. Groundwater elevation contours that cover large areas as shown in the Science and Engineering Report figure are based on a limited number of observation wells where the depth to groundwater can actually be measured. As a result, there are uncertainties associated with the exact locations of contour lines between wells. However, in this case there is an observation well located approximately 120 meters (390 feet) north of where the northern-most drift would lie. Accordingly, there is high confidence in the groundwater elevation contours in this immediate area.

7.5.3 (8887)

Comment - EIS001834 / 0028

The DEIS notes an opposing viewpoint, stating that "Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically higher than 100 meters (330 feet) above the current level, even reaching the land surface in the past (Szymanksi 1989). If such an event occurred, it would affect the performance of the proposed repository" (p. 3-49). DOE even admits, "if such an event occurred, the long term impacts would probably increase greatly" (p. 5-15). Yet, the DEIS dismisses this possibility and does not address the potential impacts of such an event.

The DEIS notes another opposing viewpoint by Davies and Archambeau which suggests that a moderate earthquake at the site could result in a water table rise of about 150 meters (490 feet) and a severe earthquake could cause a rise of about 240 meters (790 feet) in the water table, which would flood the repository. Nevada ranks third in the nation for current seismic activity. Since 1976, there have been over 600 seismic events of a magnitude greater than 2.5 within a 50-mile radius of Yucca Mountain (see attached document). The DEIS states that "earthquakes have occurred in the Yucca Mountain geologic region of influence and are likely to occur in the future" (p. 5-16). Yet, the DOE has repeatedly ignored the potential impacts of future earthquakes at the Yucca Mountain site and refuses to examine how an earthquake might affect the region's groundwater supply.

Response
Based on the results of analyses reported in Section 3.1.4.2.2 of the EIS, DOE does not believe that the waste emplacement areas would be inundated by a credible rise of the water table. Section 3.1.4.2.2 of the EIS does discuss, however, evidence that the elevation of the water table at Yucca Mountain has fluctuated over time. These fluctuations have been due largely to changes in the climate, as described in Section 3.1.4.2.2. DOE also examined the cumulative effects on the elevation of the water table from a wetter climate, earthquakes, and a volcanic eruption. Based on the evidence at hand, no reasonable combination of wetter climates, earthquakes, and volcanic eruptions could raise the elevation of the water table sufficiently to inundate waste-emplacement areas at Yucca Mountain.

Section 3.1.4.2.2 discusses several opposing views concerning fluctuations in the elevation of the water table at Yucca Mountain. These investigators believe that the water table at Yucca Mountain has risen in the past to elevations that are higher than the waste-emplacement areas. DOE does not concur with these opposing views, nor did an expert panel that was convened by the National Academy of Sciences to specifically examine this issue (as described in Section 3.1.4.2.2). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level. Although DOE disagreed with the central scientific conclusions of these investigators, DOE continues to support research in this area, as well as on other aspects of the geology and hydrology to enhance the understanding of the site.

Based on the results of analyses reported in Chapter 5 of the EIS concerning the long-term performance of the repository, which considered the effects of future seismic and volcanic activity, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with the Environmental Protection Agency's Environmental Radiation Protection Standards at 40 CFR Part 197). Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region.

It is true that Nevada ranks third, behind Alaska and California, in seismic activity. Its reputation as a highly active state comes from major historic earthquakes in western Nevada with magnitudes greater than 7 on the Richter scale. Yucca Mountain does not lie within this highly active seismic belt.

Section 4.1.8 of the EIS describes the impacts from earthquakes during operation of the repository. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on geology, geologic hazards, and the effects of these hazards on the repository, have been adequately described and analyzed in the EIS.

With regard to the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 of the Draft EIS devotes almost seven pages explaining how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3 (9212)
Comment - EIS001938 / 0001
The DEIS fails to address the potentially devastating ecological impacts of the project on the natural resources of Death Valley National Park and the surrounding region.

The DEIS fails to adequately address possible impacts of the proposed action on natural resources in and around Death Valley National Park (DVNP). At 3.3 million acres, Death Valley is without question America's most spectacular desert National Park. Nearly 3.2 million acres of the Park are designated Wilderness. The mandate of the National Park Service Organic Act of 1916 is that national parks shall be protected such that they "remain unimpaired for the enjoyment of future generations." The DEIS prepared by the DOE completely and utterly fails to ensure that Death Valley National Park will indeed remain unimpaired for future generations. Similarly, the proposed project fails to ensure that the integrity of Wilderness Areas designated by the California Desert Protection Act of 1994 will be protected, or that National Wildlife Refuge (NWR) system lands will be adequately protected from degradation. The document must be revised to assess possible impacts of the proposed action on National Park System lands, Wilderness lands, and the Ash Meadows NWR, and must detail how these critical wildlands will be protected for future generations.

The DEIS does not correctly identify the current boundaries of Death Valley National Park (nor does it identify Wilderness lands that may be affected by the proposed project). The Park was created in 1994 (see P.L. 103-433), and expanded at that time from its previous smaller size as a National Monument. Wilderness areas both within the Park and on Bureau of Land Management (BLM) lands in the region surrounding the National Park were also designated at that time (see ibid.). The additional National Park Service (and Wilderness) lands that could be impacted by contamination from the repository must be disclosed in the final draft, and the potential impact of the project on *all* the lands within this unit of the National Park System – including possible radioactive leakage to groundwater and surface water resources of the Park, as well as possible impacts on resources within the expanded Parklands from accidents involving transport of high level nuclear waste -- must be analyzed. Without accurately identifying the boundaries of DVNP, or of designated Wilderness areas, it is impossible for the DEIS to contain a complete and thorough analysis of possible impacts of the project on the resources contained within DVNP and surrounding wildlands.

DVNP proper contains spectacular mountain ranges and vistas, desert bighorn sheep and other wildlife, and riparian resources including Salt Creek, Saratoga Springs, and numerous springs and seeps, all of which are the lifeblood for numerous plant, animal, bird and fish species, many of them unique to Death Valley. The Devil's Hole Detached Unit of DNVP and the Ash Meadows NWR, both in the Amargosa Valley, contain an amazing system of natural springs and seeps at Ash Meadows. This extensive above-ground aquifer harbors threatened and endangered species including the Devil's Hole pupfish and other endemic flora and fauna. The DEIS not only does not contain an adequate description of these resources, it provides little, if any, analysis of the proposed project on impacts to the natural environment.

3.2 million acres of Death Valley National Park are designated Wilderness. Additional BLM Wilderness areas surround Death Valley. Places like the Kingston Range Wilderness, Resting Spring Wilderness, the Nopah Range Wilderness and Pahrump Valley Wilderness not only contain important natural resources (e.g., springs, flora and fauna, wildlife habitat, archaeological resources), these Wilderness [areas] provide outstanding opportunities for primitive recreation including hiking, backpacking, hunting and nature study. Yet the DEIS has failed to acknowledge possible impacts of the proposed action on these wilderness lands and on wilderness-related recreation.

Response

DOE has conducted an extensive site characterization program to evaluate the proposed repository at Yucca Mountain. The general path of the water that percolates through Yucca Mountain is south toward the Amargosa Valley, into and through the area around Death Valley Junction in the lower Amargosa Valley. Groundwater from beneath Yucca Mountain would merge and mix with underflow from Fortymile Wash and then flow and mix into the very large groundwater reservoir in the Amargosa Desert, where it would move slowly due to the high effective porosity of basin deposits. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume might flow south toward Tecopa in the Southern Death Valley subregion. In addition, a small percentage of the groundwater might flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains toward spring discharge points in the Furnace Creek area of Death Valley.

Sparse potentiometric data indicate that a divide could exist in the Funeral Mountains between the Amargosa Desert and Death Valley. Such a divide would limit discharge from the shallow flow system, but would not necessarily affect the deeper carbonate flow system that could contribute discharge to the Furnace Creek area (DIRS 100465-Luckey et al. 1996). Geochemical, isotopic, and temperature data indicate that water discharging from springs in the Furnace Creek area is a mixture of water from basin-fill aquifers in the northwestern Amargosa Desert and the deeper flow in the regional carbonate aquifer (DIRS 101167-Winograd and Thordarson, 1975). The groundwater in the northwestern part of the Amargosa Desert originates in the Amargosa River drainage in Oasis Valley and from the eastern slope of the Funeral Mountains, both of which are west of the flow paths that extend south from Yucca Mountain. Even if part of the flow from Yucca Mountain mixed into the carbonate pathway that supplies the Furnace Creek springs, it would be too little to significantly affect the springflow chemistry. Considering the small fraction of water that would infiltrate though the repository footprint (approximately 0.2 percent or less) compared to the total amount of water flowing through the basin and the large distances involved [more than 60 kilometers (37 miles) from the source], any component from Yucca Mountain in this very long and complicated flow path would be diluted to such an extent that it would be undetectable.

The National Park Service administers the Devils Hole Protective Withdrawal in addition to Death Valley National Park. The southward path of the groundwater that infiltrates Yucca Mountain includes flow in the Amargosa Desert near Ash Meadows and Devils Hole. In this area there is a marked decline of 64 meters (210 feet) or more in the elevation of the water table between Devils Hole and the low axis (Carson Slough) of the Amargosa Desert to the west and south. This elevation decline indicates that potential groundwater flow from the carbonate rocks of the Devils Hole Hills is westward across Ash Meadows toward the Amargosa Desert, not the other way around. Therefore, potential contamination from Yucca Mountain could not discharge to the surface or contaminate the aquifers at Ash Meadows or Devils Hole under present or likely future climates.

The assessment of long-term repository performance shows that the combination of natural and engineered barriers at the site would keep the doses resulting from releases of radionuclides well below the regulatory limits specified in 40 CFR Part 197 and would keep any release small enough to pose no significant impact on the health and safety of people or the environment. If a small fraction of the water that percolated through the repository footprint flowed into the Furnace Creek area in Death Valley, the mean peak dose would be less than the dose calculated for Franklin Lake Playa. Sections 3.1.4.2.1, 3.1.4.2.2, and 5.4 of the EIS contain additional information.

7.5.3 (9218)
Comment - 010294 / 0002
Define the Capable Faults under the NRC [Nuclear Regulatory Commission] regulations for Nuclear Generating Station Siting.

Response
A "capable fault," as defined in 10 CFR Part 100 (Reactor Site Criteria), is not applicable to Yucca Mountain. The Nuclear Regulatory Commission has developed site-specific standards for Yucca Mountain at 10 CFR Part 63, which include seismic standards.

To answer your question, however, 10 CFR Part 100 defines a capable fault as exhibiting one or more of the following characteristics: (1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years; (2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault; (3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

7.5.3 (9800)
Comment - EIS001888 / 0386
[Clark County summary of a comment it received from a member of the public.]

A commenter indicated that the EIS should provide the technical basis to establish a groundwater-monitoring network during the pre- and post-closure phases of the repository, believing that groundwater quality, quantity, and flow in the saturated and unsaturated zones at Yucca Mountain will not be adequately known.

Response
Section 2.1.2.3 of the EIS describes, in general terms, the types of tests, experiments, and analyses DOE would conduct under the repository performance confirmation program. The types of data collected would include air temperature and humidity in the emplacement drifts; the physical condition of waste packages and drifts; groundwater flow or seepage into the drifts; saturated-zone monitoring; and others. These parameters and some of the others identified in this EIS might not be those envisioned by this commenter for monitoring radionuclide migration, but their purposes overlap those described in the comment. The purpose of the performance confirmation program is to evaluate and determine the adequacy of the information used to demonstrate compliance with performance objectives (see Chapter 5). The program would be implemented during all phases of repository construction and operation and continue until the start of closure activities. The long-term performance assessment predicts there would be no release of radiological contaminants from the repository system during the operational period (and for much longer thereafter). However, the performance confirmation program would confirm both that subsurface conditions were consistent with the assumptions used in performance analyses and that barrier systems and components operated within the expected bounds.

In addition, DOE has installed a series of test wells along the groundwater flow path between the Yucca Mountain site and the Town of Amargosa Valley as part of an alluvial testing complex. The objective of this program is to better characterize the alluvial deposits beneath Fortymile Wash along the east side of Yucca Mountain. Single- and multi-well tracer tests have begun and the results thus far have strengthened the basis of the site-scale saturated flow and transport model. Information from this program has been incorporated in the EIS.

7.5.3 (10242)
Comment - EIS001888 / 0591
We have reviewed the Environmental Impact Draft Study (EIDS) [Draft Environmental Impact Statement (Draft EIS)], and have found many areas [that] have been completely over looked.

There were no studies or surveys done in the following areas:

Faults, Possible Earthquakes, Underground Water

The builders of the Titanic believed it was unsinkable, so did those who purchased tickets, so did the press." Now, we know different. Several months ago we experienced an earthquake. It took place at an unnamed fault, unnamed because it was believed by "authorities" in the field to be inactive. Now, we know different.

Response
Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults and future seismicity. Section 4.1.8 describes the impacts from earthquakes during operation of the repository. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on geology, geologic hazards, and the effects of these hazards on the repository, have been adequately described and analyzed.

Section 3.1.4.2 of the EIS contains a detailed discussion of groundwater at and near Yucca Mountain. Several subsections to 4.1.3 describe the impacts to groundwater during operation of the repository. Section 5.4 describes the long-term consequences to groundwater. Several subsections of 8.2 and 8.3 examine the cumulative impacts to groundwater from the repository, the Nevada Test Site, and other activities in the area that could contribute to long-term groundwater pollution. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on faults, earthquakes, and groundwater is adequately described and analyzed in the EIS.

7.5.3 (10284)
Comment - EIS002094 / 0002
Not only earthquakes, but fast flowing water, crustal expansion, escape pathways for radioactive gases and the possible presence of a magma pocket all plague the site. Most significant of all is the underground aquifer which will carry harmful doses of leaking radiation to human communities downstream for hundreds of thousands of years into the future.

Response
As discussed in Section 3.1.3.3 of the EIS, DOE has been monitoring earthquake activity at and near the Nevada Test Site since 1978. DOE has investigated faults and earthquakes during the site characterization program to provide information needed to assess seismic hazards at the site. DOE recognizes there is a seismic hazard at Yucca Mountain, but with proper design a repository can operate safely over the long term. Using seismic hazard information, surface facilities at the repository would be designed to withstand the effects of earthquakes that might occur during the lifetime of these facilities. The seismic design requirements for the repository specify that structures, systems, and components important to safety must be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is equivalent of an earthquake of magnitude 6.3 within 5 kilometers (3 miles) of Yucca Mountain.

As stated in EIS Section 3.1.3.3, Wernicke et al. (DIRS 103485-1998) claim that crustal strain rates in the Yucca Mountain area are higher than would be predicted from the geologic and tectonic history. If the higher strain rates are valid, the potential seismic and volcanic hazards would be underestimated. In May 1998, scientists with the U.S. Geological Survey conducted a reassessment of crustal strain Savage, Svarc, and Prescott (DIRS 118952-1999). The principal strain rates determined over the 1983 through 1998 survey interval confirmed previous analyses and were significantly less than reported by Wernicke et al. The Survey concluded that the residual strain rate in the Yucca Mountain area is not significant at the 95 percent confidence level after removing the effects of the 1992 Little Skull Mountain earthquake and the strain accumulation on faults in Death Valley.

DOE continues to fund additional research on the regional crustal strain rate in the Yucca Mountain region through a cooperative agreement with the University of Nevada. Dr. Wernicke, the principal investigator of one study, recently estimated in a quarterly report to the DOE that conclusions from this study would be available in 2002. If the higher crustal strain rates are confirmed, DOE will reassess the volcanic and seismic hazards at Yucca Mountain.

Faults and fractures at the site represent potential pathways for radionuclide migration from the proposed repository. Section 3.1.4.2.2 of the EIS discusses groundwater at Yucca Mountain. The chlorine-36 analyses identified locations where water has moved fairly rapidly from the surface to proposed repository depths, as well as locations where water has moved relatively slowly. Additional age-dating evidence indicates that the groundwater in the lower carbonate aquifer is at least 10,000 to 20,000 years old, which is the approximate age of the groundwater in the overlying volcanic aquifer. These apparent ages indicate that the water in these aquifers was recharged during a wetter and colder climate. The age of the groundwater and the relatively flat hydrologic gradient beneath the site (DIRS 151945-CRWMS M&O 2000) indicate that groundwater beneath the site is moving at a relatively slow rate.

Chapter 5 of the EIS discusses the long-term performance of the proposed repository, which includes predictions of impacts from radioactive and nonradioactive materials released to the environment during the first 10,000 years after repository closure. The principal means or pathways by which these materials would be released is movement through the unsaturated zone beneath the repository and then into the groundwater system. The Yucca Mountain site characterization effort has centered around learning enough about the site to make reasonable projections about how and when contaminants would enter the environment.

The long-term impacts of the repository described in the EIS are based on forecasts involving what the future environment would be like and how natural subsurface features vary over distance. There is some uncertainty associated with these types of forecasts, particularly when they must account for thousands of years and long distances. Section 5.2.4 of the EIS discusses how DOE addressed these uncertainties. Section 5.2.4 also addresses the possible effects that uncertainties could have on the impacts described in the EIS, concluding that the current performance assessment is a "snapshot in time" that would continue to be refined with additional work. DOE believes that the expected performance of the repository, as described in the EIS, is a conservative estimate, and that additional work will increase confidence in how the repository would perform over the long term.

7.5.3 (10420)
Comment - EIS001927 / 0030
Why will Yucca Mountain fail to isolate nuclear waste? The answer is very simple. Yucca Mountain is as seismically active as San Francisco Bay. Indeed, Nevada is the third most earthquake prone State in the Union after Alaska and California. Riddled with dozens of fault lines, there's a whole lot shaking going on at Yucca Mountain. Well over 600 earthquakes with a magnitude greater than 2.5 on the Richter scale have struck within 50 miles of the proposed repository site in the past 25 years along. A 5.6 jolt, centered less than 10 short miles from Yucca Mountain, did serious damage to the DOE field office in June, 1992. In the past few years, the tremors seem to have increased in frequency. Just last fall, a quake derailed a train on a proposed repository transport route.

What does this mean for the proposed Yucca Mountain repository? Researcher Jerry Szymanski has concluded that the level of the water table has risen dramatically – perhaps over 100 meters higher than the current level – in the past. Other researchers, Davies and Archambeau, predict that a small earthquake at Yucca Mountain could raise the water table 150 meters, while a severe earthquake could raise the level nearly 250 meters – high enough to flood the repository. Such a catastrophe would lead to early breaching of waste casks and a massive release of radioactivity into the groundwater below. The DEIS admits that such a scenario is possible, but leaves it at that, not addressing the potential environmental impacts.

All this shaking has fractured the relatively soft rock (volcanic tuff) that forms this low snaking ridge. The entire mass of Yucca Mountain is a sieve with tiny fractures that allow water and gas to flow in and out, which is not exactly ideal for isolating deadly nuclear wastes.

Response
DOE recognizes that there is a seismic hazard at Yucca Mountain. However, with proper design, the combination of natural and engineered barriers at the site would keep any doses resulting from releases of radioactive materials from the repository within the regulatory limits established by the Environmental Protection Agency at 40 CFR Part 197.

DOE has conducted many studies to quantify the seismic hazard at Yucca Mountain. Based on these studies, the Department would design facilities that are important to safety to withstand appropriately large ground motions from earthquakes. Seismic effects have also been taken into account in assessing the long-term performance of a potential repository at Yucca Mountain.

While large earthquakes are possible in the vicinity of Yucca Mountain, it is not expected that any would be as large as the largest that could occur in the San Francisco Bay area. In addition, the recurrence interval for large earthquakes near Yucca Mountain is significantly longer than for large earthquakes along the San Andreas Fault in California. For example, the seismic event that occurred along the Solitario Canyon fault about 70,000 years ago (based on detailed mapping and sampling in trenches) would be equivalent to only a notable fault in the San Francisco Bay area. Moreover, the recurrence interval for a comparable earthquake along the northern San Andreas Fault is about 200 to 250 years.

As part of site characterization activities, DOE monitors the seismic activity in the Yucca Mountain region. Since 1975, more than 1,500 earthquakes with a magnitude exceeding a magnitude of 2.5 have occurred within 80 kilometers (50 miles) of the site, including the magnitude 5.6 earthquake at Little Skull Mountain in 1992. Some of the small-magnitude events (magnitude 2.5 and less) might not represent an increase in seismicity, but rather the greater sensitivity of new instrumentation.

Repository facilities that are important to safety would be designed to withstand appropriate levels of ground motion and fault displacement. To the extent practical, such facilities would be sited to avoid faults that can rupture the surface. The facilities damaged in the 1992 Little Skull Mountain earthquake were built in the 1960s and were not designed to accommodate the levels of ground motion for which the repository facilities would be designed.

Transportation casks that would be used to convey radioactive waste to Yucca Mountain would have to be certified by the Nuclear Regulatory Commission. To earn that certification, the casks must pass a drop test that simulates a transportation accident similar to the impact of a train derailment, whether caused by an earthquake or other means.

DIRS 106963-Szymanski (1989) proposed that during the last 10,000 to 1,000,000 years, hot mineralized groundwater was driven to the surface by earthquakes and volcanoes. This hypothesis goes on to suggest that similar forces could raise the regional groundwater table in the future and inundate the waste emplacement horizon.

DOE requested that the National Academy of Sciences conduct an independent evaluation. The Academy concluded (DIRS 105162-National Research Council 1992) that no known mechanism could cause a future inundation of the repository horizon. The features cited by Szymanski as proof of groundwater upwelling in and around Yucca Mountain are related to the much older (13 to 10 million years old) volcanic process that formed Yucca Mountain and the underlying volcanic rocks.

Yucca Mountain Project scientists have estimated that the water table could rise by 50 to 130 meters (160 to 430 feet) under extremely wet climatic conditions. The regional aquifer has been estimated to have been a maximum of 120 meters (390 feet) above the present level beneath Yucca Mountain during the past million or more years based on mineralogic data, isotopic data, discharge deposit data, and hydrologic modeling. The occurrence of an earthquake under these extreme climatic conditions might cause an additional rise in the water table of less than 20 meters (66 feet), still leaving a safety margin of 20 meters or more between the water table and the level of the waste emplacement drifts. The 1992 Little Skull Mountain earthquake (magnitude 5.6) raised water levels in monitoring wells at Yucca Mountain a maximum of less than 1 meter (3.3 feet) (DIRS 101276-O'Brien 1993). Water level and fluid pressure in continuously monitored wells rose sharply and then receded over a period of several hours to pre-earthquake levels. The water-level rise in hourly monitored wells was on the order of centimeters and indistinguishable after 2 hours (DIRS 101276-O'Brien 1993).

Dublyansky (DIRS 104875-1998) proposed another line of evidence in support of the warm-water upwelling hypothesis. This study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. The report concludes that some of these crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of project scientists with expertise in hydrology, geology, isotope geochemistry, and climatology did not concur with Dublyansky's conclusions (DIRS 100086-Stuckless et al. 1998). Although DOE disagrees with the central scientific conclusions of Dublyansky's report, it agreed to support continuing research by Jean Cline at the University of Nevada, Las Vegas. Section 3.1.4.2.2 of the EIS contains additional information.

With regard to the rock at Yucca Mountain acting like a sieve, DOE has encountered many fractures in the course of excavating more than 11 kilometers (6.8 miles) of tunnels and test alcoves at Yucca Mountain, and only one fracture was moist. Further observations in testing alcoves that have been isolated from the effects of tunnel ventilation for several years confirm the lack of natural seepage at the waste emplacement level (DIRS 151945-CRWMS M&O 2000).

7.5.3 (10748)
Comment - EIS001886 / 0001
The EIS is premature and scientifically unsound

The presumption in the Draft EIS is that the repository will be unsaturated -- that is it will not at any relevant time have a significant probability of flooding with water. As the attached comments by Dr. Yuri Dublyansky show, the DOE's assumption is unsound. The DOE's reasoning in summarily dismissing the evidence for repository flooding in the geologic past is based on misleading and selective use of information. There is a good deal of evidence indicating flooding of the repository. There is also some evidence of relatively recent flooding (in geologic terms). The entire Yucca Mountain repository program is based on the assumption of an unsaturated repository. Given the centrality of this issue, the DOE should re-issue a draft EIS with its analysis of the environmental consequences of such flooding, so that the public can evaluate it on its merits.

Moreover, as is noted in Dr. Dublyansky's comments, the DOE has ignored the ongoing work that it has commissioned and is being performed by Dr. Jean Cline at the University of Nevada, Las Vegas [UNLV]. This DOE-funded program of research followed the publication of a report on the subject by Dr. Dublyansky that was commissioned by IEER [Institute for Energy and Environmental Research]. The results of that work were published by IEER in December 1998. The DOE project aims to confirm or negate earlier findings of hydrothermal incursions of groundwater into the repository horizon as well as to determine the date(s) in the geologic past when such incursion(s) might have occurred. The preliminary data from this work confirm the earlier work of Dr. Dublyansky. The project has not yet determined any dates for the hydrothermal events. The UNLV research will not be complete until well into 2001. Yet the DOE plans to publish its final EIS in the year 2000.

With the major exception of geologists involved with the Yucca Mountain Project, there is now widespread agreement that at some time in the geological past there were likely to have been hydrothermal incursions into the Yucca Mountain repository region. One or more such incursions in the future would utterly alter the analysis of repository impacts. This is therefore a crucial factor in projecting the performance of the proposed repository.

Were the issue being considered a marginal one, this sequence might, in some circumstances be considered acceptable. However, the questions of saturation and time of saturation are the central ones in determining repository performance. The Draft EIS is therefore premature. It should be re-issued in late 2001, at the earliest, after the UNLV findings have been published, peer-reviewed and their significance for the proposed repository has been carefully assessed.

If a Final EIS is completed without the data and analysis on hydrothermal incursions being fully taken into account in the assessment of impacts, the FEIS will be so basically deficient as to be invalid.

Besides the issue of hydrothermal incursions, the DOE needs to take fully into account the potential for the metal canisters to corrode in relatively short time periods (say, a few hundred years or less) if the repository is unsaturated but far more humid than has been assumed. Further, under such circumstances, the DOE also needs to factor in the potential for the rapid disintegration of the borosilicate glass waste form due to hydration aging.[1] Finally, the DOE needs to factor in the potential for far more rapid migration of plutonium and other actinides than has been assumed.

[1]Arjun Makhijani, Glass in the Rocks: Some Issues Concerning the Disposal of Radioactive Borosilicate Glass in a Yucca Mountain Repository, prepared for the Nevada Nuclear Waste Task Force and the Nevada Agency for Nuclear Projects, Nuclear Waste Project Office, State of Nevada. Takoma Park, Maryland: Institute for Energy and Environmental Research, January 29, 1991.

Response

Intensive investigations by DOE identified no evidence or credible mechanisms to rise the elevation of the groundwater to flood the repository horizon in the vicinity of Yucca Mountain. Opposing views by Szymanski (DIRS 106963-1989) and Dublyansky (DIRS 104875-1998) are discussed in Section 3.1.4.2.2 of the EIS.

DIRS 106963-Szymanski (1989) proposed that during the last 10,000 to 1 million years, hot mineralized groundwater was driven to the surface by earthquakes and volcanic activity. This hypothesis goes on to suggest that similar forces could raise the regional groundwater in the future and inundate the repository horizon.

DOE requested that the National Research Council render an independent evaluation of the issue. After reviewing available information, the National Research Council concluded that no mechanism was known that could cause a future inundation of the repository horizon (DIRS 105162-National Research Council 1992). The features cited by Szymanski as proof of groundwater upwelling in and around Yucca Mountain are related to the much older (13 to 10 million years old) volcanic process that formed Yucca Mountain and the underlying volcanic rocks. Significant water table excursions (exceeding tens of meters) to the design level of the repository due to earthquakes are unlikely. Section 3.1.3.1 of the EIS discusses the likelihood of volcanic activity in the area is low (1 chance in 70 million annually); if it occurred, it would probably raise the water table a few tens of meters, at most.

Scientists working on the Yucca Mountain Site Characterization Project have estimated that the water table could rise by 50 to 130 meters (160 to 430 feet) under extremely wet climatic conditions. The regional aquifer has been estimated to have been as much as 120 meters (390 feet) above the present groundwater elevation beneath Yucca Mountain during the past million or more years based on mineralogic data, isotopic data, discharge deposit data, and hydrologic modeling analysis. The occurrence of an earthquake under these extreme climatic conditions might cause an additional rise in the water table of less than 20 meters (66 feet), still leaving a safety margin of 20 meters (66 feet) or more between the water table and the level of the repository emplacement drifts. The 1992 Little Skull Mountain magnitude 5.6 earthquake raised water levels in monitoring wells at Yucca Mountain less than 1 meter (DIRS 101276-O'Brien 1993). Water level and fluid pressure in continuously monitored wells rose sharply and then receded, over a period of several hours, to pre-earthquake levels. The water level rise in hourly monitored wells was on the order of centimeters and indistinguishable after 2 hours (DIRS 101276-O'Brien 1993).

Dublyansky (DIRS 104875-1998) proposed another line of data in support of the warm-water upwelling hypothesis. This study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. The report concludes that some of these crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of project scientists with expertise in hydrology, geology, isotope geochemistry, and climatology did not concur with the conclusions in the report (DIRS 100086-Stuckless et al. 1998). Although DOE disagreed with the central scientific conclusions in this report, DOE agreed to support continuing research. An independent investigation by Jean Cline, University of Nevada, Las Vegas, should be completed in fiscal year 2001.

The repository would be above the water table in the unsaturated zone. Therefore the most important process controlling waste package corrosion is whether water would drip from seeps onto the waste package. Field and laboratory testing indicate that seepage would be limited and the location of the seeps would depend on fracture-matrix and drift wall interactions. Under the present design, the radioactive waste that is placed in the repository would be enclosed in a two-layer waste package and covered by a titanium drip shield. The waste package would have a chromium-nickel alloy outer layer and a stainless-steel inner layer. These materials have extremely low corrosion rates and are not expected to fail for thousands of years.

The results of studies on the degradation of borosilicate glass reported in the EIS are based on the most current models available. These models account for several alternative conceptual models (including vapor-phase degradation). They are based on the most recent data available. The models have been validated against degradation of natural basaltic glasses over very long periods in seawater. At a pH of 8 the model predicts a corrosion rate of 9×10^{-6} gram per square meter per day. The natural glass samples had been exposed to silicon-saturated seawater and had corrosion rates of 0.1 micrometers in 1000 years. This would correspond to 6×10^{-7} gram per square meter per day. Thus, the degradation models for glass in the repository performance assessment are conservative by nearly an order of magnitude.

At the Benham nuclear test site on the Nevada Test Site, rapid transport of colloid-associated plutonium was noted. The results of groundwater monitoring indicate that a small fraction of plutonium has migrated 1.3 kilometer (0.8 mile) from the blast site in 30 years. In fracture systems, colloids that are repelled from the wall rock may move even faster than nonsorbing dissolved species because they remain in the faster flowing portions of the flow paths. Plutonium colloidal transport has been included in the analysis and is the subject of continuing and additional work.

Ongoing studies suggest that water travels through the unsaturated zone at highly variable rates. Groundwater travel times for contaminants from the repository that enter the accessible environment (specified in 40 CFR Part 197) are on the order of thousands to tens of thousands of years. The natural discharge of groundwater from beneath Yucca Mountain probably occurs far to the south at Franklin Lake Playa more than 60 kilometers (37 miles) away and travel times would be even longer. The long-term performance assessment (modeling) analysis show that the combination of natural barriers of the site and engineered barriers keep the radionuclides well below the regulatory limits established at 40 CFR Part 197. See Sections 3.1.3, 3.1.4.2, and 5.4 of the EIS for additional information.

7.5.3 (10757)
Comment - EIS001886 / 0010
Draft EIS (as well as released earlier Viability Assessment) is a model illustrating how critical decisions regarding the fate of nuclear waste will be made, and on what sort of science these decisions will be based. Having spent more than 15 years and several billion dollars to characterize the Yucca Mountain site, DOE and its contractors have produced tremendous amount of highly technical information. It is contained in millions of pages of reports and publications. Final Environmental Impact Statement, as well as all other documents that will provide basis for legal decisions must be based on careful evaluation of all pertinent information contained there. It is exceedingly important not to leave any information that has bearing on the performance of the repository beyond the scope of the analysis.

Decisions regarding what is important and what is less important and may, therefore, be omitted, can only be made by highly qualified professionals. We find it incredible that among 30 members of the Draft EIS preparation team only one has a degree in geology.* We do not believe that one Bachelor of Science, however brilliant he may be, may be put in position of being responsible for evaluation and compilation of 15 year-worth work of several organizations and tens of researchers that cover substantial number of very specific and intricate fields of Earth Sciences.

*Jeffrey McCann; B.S., Geological Sciences, 1980. US DOE 1999, pp. 13-1 -- 13-7.

Response
The EIS team prepared the text of the EIS and decided on such things as the amount of information to be included in the EIS and the level of technical detail. The information and the analyses in the EIS, however, were developed by many people who were not on the EIS team, but who authored many of the references cited in the EIS (for example, geologists working for the U.S. Geological Survey). In addition, several senior geologists and hydrologists from DOE and its Management and Technical Services Contractor (Booz Allen & Hamilton) performed extensive reviews of the integrated material presented in the Final EIS. Moreover, several drafts of the EIS were reviewed by geologists not associated with the project to make sure that the information presented was accurate.

From the inception of the Yucca Mountain Project, DOE has included individuals with expertise in geology, including staff from the U.S. Geological Survey. When needed, DOE has elicited opinions from recognized experts in academia, industry, and government to address specific topics. For these reasons, the Department believes that the quantity, quality, and experience of the geological expertise applied to the EIS have been more than adequate.

7.5.3 (11037)
Comment - 010122 / 0004
The department can't use water that it doesn't have. The waste water from the fuel pools and from washing down the transportation casks would go through an ion exchange, supposedly trapping all the radionuclides in a filter. The water would then go to evaporation pools while the filters would be disposed of as low-level radioactive waste, on the Test Site, of course.

Response
The Final EIS recognizes that the Nevada State Engineer denied DOE's application for permanent water rights to support construction, operation, and maintenance of the proposed repository. The application was denied on the basis that the proposed use threatens to prove detrimental to the public interest because that use is prohibited by existing state law. DOE disagrees with this finding and, through the Department of Justice, filed an appeal of the State Engineer's decision. On October 15, 2001, the Ninth U.S. Circuit Court of Appeals ordered a Federal judge to hear DOE's suit. The case is pending.

With respect to the management of low-level radioactive waste, the comment is correct that DOE proposes to dispose of such waste at the Nevada Test Site where adequate disposal capacity is available. The comment's description of the management of wastewater is, however, not accurate. There would be no evaporation pools for the treatment of low-level radioactive wastewater. There would be an evaporator component among the processes that would be used to clean water for recycling within the facility, but it would be a closed component with the condensate (that is, the portion evaporated and subsequently condensed back to liquid) being the material recycled. Liquid low-level radioactive waste that could not be recycled would be stabilized prior to shipment for disposal.

7.5.3 (11673)
Comment - EIS002295 / 0005
Yucca is a ridge not a mountain.

Response
DOE agrees that, as a landform, Yucca Mountain consists of a series of ridges.

7.5.3 (11924)
Comment - 010326 / 0002
And talking about the surface water, again I'm coming along where other people have mentioned this, but talking about the new systems that are being put in place, suggestions for the pool where they're going to be cooling down rods, spent rods, and that is also going to be affecting, or could be affecting our water.

Response
As indicated in Section 3.1.3 of the Supplement to the EIS and Section 4.1.3 of the EIS, surface facilities at the proposed repository would not affect the quality of surface water or groundwater. As described in Section 4.1.3.2 of the EIS, the construction of surface facilities at Yucca Mountain would be required to withstand a flood magnitude appropriate for the risk posed by the facility. That is, facilities where radioactive materials would be managed would be designed to withstand the probable maximum flood (this includes a possible spent nuclear fuel surface aging area that would be used to achieve lower-temperature operating conditions in the repository). Other facilities would be designed to withstand a 100-year flood. Appendix L of the EIS contains an assessment of the affects of flooding along major washes at Yucca Mountain. This analysis was conducted pursuant to Executive Order 11988, Floodplain Management, and in compliance with DOE's regulations that implement this Executive Order (10 CFR Part 1022, *Compliance with Floodplain/Wetlands Environmental Review Requirements*).

7.5.3 (12141)
Comment - EIS001933 / 0003
You know there are active fault lines and water coming up.

Response
Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults. Section 4.1.8 of the EIS describes the impacts of earthquakes during operation of the repository. Several sections in Chapter 5 of the EIS consider earthquakes and their effects on the performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on seismic activity and the effects of this activity on the repository is adequately described and analyzed.

Section 3.1.4.2.2 of the EIS discusses fluctuations in the elevation of the water table at Yucca Mountain caused by changes in the climate. This section also discusses several opposing views by investigators who believe that the water table at Yucca Mountain has risen in the past to elevations that are higher than the subsurface waste-emplacement areas. DOE does not concur with these opposing views, nor did an expert panel that was convened by the National Academy of Sciences to specifically examine this issue. DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level.

7.5.3 (12159)
<u>Comment</u> - 010327 / 0002
I'm very concerned that there's so much talk about water flow. It's very disconcerting to me that there is so much design fortification around water issues when the DOE talks about Yucca Mountain being so dry and the perfect place for waste. It's confusing to me.

<u>Response</u>
The environment of Yucca Mountain and surrounding areas is arid. The depth to groundwater is about 750 meters (2,500 feet) below the crest of Yucca Mountain. Under the proposed action, DOE would emplace the waste 160 to 400 meters (525 to 1,300 feet) above the water table. While the waste-emplacement area is dry, very small amounts of surface precipitation do move slowly through the rocks to the level of the proposed repository. To increase the confidence in the safe, long-term performance of the repository, the Department has included titanium drip shields that would cover the waste and divert any water that might infiltrate to these depths away from the waste casks. This design was carried forward to the Final EIS. This design is described in the Supplement to the Draft EIS, along with other new operating and design features. Even though the amount of water that could reasonably be expected to infiltrate to the depth of the emplaced waste is very small, DOE has nevertheless proposed to enhance the already substantial engineered and natural barriers to radionuclide transport.

7.5.3 (12422)
<u>Comment</u> - 010375 / 0008
Flooding, earthquakes that have done damage, what about larger ones?

<u>Response</u>
As described in Section 4.1.3.2 of the EIS, the construction of surface facilities at Yucca Mountain would be required to withstand a flood magnitude appropriate for the risk posed by the facility. That is, facilities where radioactive materials would be managed would be designed to withstand the probable maximum flood (this includes a possible spent nuclear fuel surface aging area that would be used to achieve lower-temperature operating conditions in the repository). Other facilities would be designed to withstand a 100-year flood. None of the estimated floods described in Appendix L (including the regional and probable maximum floods) would reach the height of the portals to the subsurface facilities. In summary, DOE believes that the largest floods that could reasonably be expected to occur at Yucca Mountain would not pose a threat to either surface or subsurface facilities, although flooding could temporarily interrupt vehicle traffic.

As discussed in Section 3.1.3.3 of the EIS, DOE has been monitoring seismic activity and studying the geologic structure at and near Yucca Mountain since 1978. Using these data and the results of these studies, along with input from panels of recognized experts on seismic risks and hazards, DOE would design surface facilities at the repository to withstand the effects of earthquakes that might occur during the lifetime of the facilities. The seismic design requirements for the repository specify that structures, systems, and components that are important to safety must be designed to withstand horizontal ground motion with an annual frequency of occurrence of once in 10,000 years. This is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain. The largest recorded earthquake within 50 kilometers (31 miles) of Yucca Mountain occurred in 1992 at Little Skull Mountain 20 kilometers (12 miles) southeast of Yucca Mountain.

7.5.3 (12556)
<u>Comment</u> - 010390 / 0002
The S&ER [Science and Engineering Report] addresses monitoring of the unsaturated and saturated zones for potential migration of radionuclides from the repository. One monitoring well located up-gradient, and four monitoring wells located down-gradient from the site are proposed. The final EIS should be amended to include a more detailed description of the proposed ground water monitoring plan and the rationale behind the monitoring system design.

Any potential radionuclide release would likely affect the perched water aquifer prior to deeper aquifers. Additionally, the perched water aquifer may be an important factor influencing the hydraulic gradient within the volcanic aquifer and subsequently any potential plume migration. Therefore, the final monitoring system design should be based on an improved hydrogeologic model, including an improved characterization of the perched water and volcanic/carbonate aquifers as well as any pertinent information obtained during the repository construction and performance confirmation program.

The proposed monitoring of the unsaturated zone, repository drifts and nuclear waste containment units is comprised of observation drifts and alcoves, equipped with monitoring instruments placed either in the emplacement drifts and/or in boreholes. The proposed monitoring appears to be adequate for this stage of the investigation. However, the final unsaturated zone monitoring plan design should be based on the thermal load operating mode and results of the ongoing thermal drift-scale and seepage tests. In addition, the final EIS should include a detailed description of the proposed monitoring device(s).

Response
Section 2.1.2.3 of the EIS briefly describes performance confirmation activities, including monitoring, that would take place during construction, operation, and through closure of the repository. DOE believes that this information is adequate for the EIS. Should the proposed action be implemented, the Department would develop detailed monitoring plans.

Monitoring during performance confirmation would involve activities similar to the current characterization activities at the Yucca Mountain. The environmental impacts of these activities would be negligible. DOE understands, however, that there are members of the public who are very interested in this element of the proposed action. Accordingly, the Department will continue to make monitoring information available in documents, such as the *Yucca Mountain Science and Engineering Report* (DIRS 153849-DOE 2001) and a Performance Confirmation Plan, that focus more on the technical detail of the Proposed Action.

DOE agrees that possible effects of the repository on perched water bodies could be important to the overall performance of the system. The Science and Engineering Report states that "Key geologic, hydrogeologic, geomechanical, and other physical processes or factors (and related parameters) will be monitored and tested throughout construction, emplacement, and operation to detect any significant changes from baseline conditions" (DIRS 153849-DOE 2001). Continued definition of the performance confirmation is ongoing and would be described in the license application in more detail, including the rational of design.

7.5.3 (12689)
Comment - 010480 / 0001
On page 2-25 under Design Evaluation. Water dripping on waste packages would increase the likely hood of corrosion. What kind of water? Already contained from underground testing? And the mixing of radionuclides which at this point no one know really what lies in the water below Yucca Mountain. Tritium was found but filtered out.

Other brush under the rug. This could bring a problem if you don't know the contents of the water that is going to drip on the shield. What about the perched water? Could it drip on the shield or maybe you found all the perched water. You could drill holes all over that mountain and never find, all the perched water or where all the water may be found.

Underground testing and the buried waste don't mix. Not only don't the water mix but we can't find out if the underground testing has got into the water or the Tuff and could seep down on the shields or perk up from below with a sudden movement form the Mother Earth. And lets don't forget about the content of the water dripping and radionuclides and the mixing of [divergent] isotopes.

Response
DOE recognizes that corrosion of the waste packages would be more rapid if liquid water dripped directly on the packages. This is one of the reasons the design described in the Supplement to the Draft EIS included titanium drip shields that would cover the waste packages. These shields would be made of different material than the waste packages; thus, their degradation would be driven by different processes. While intact, the drip shields would

protect the waste packages from falling rocks as the drifts degrade, as well as protect the waste packages from any possible dripping water (the waste packages would still be the primary engineered barrier to radionuclide transport). DOE added this second line of defense primarily as an additional layer of conservatism for the licensing safety case and to compensate for large uncertainties in the corrosion rates of the waste package materials.

As described in Section 3.1.4.2.2 of the EIS, DOE has discovered elevated concentrations of "bomb-pulse" chlorine-36 and tritium at depth in Yucca Mountain. Anomalous concentrations of these isotopes are believed to be from atmospheric testing of nuclear weapons during the 1950s and 1960s. At Yucca Mountain, these isotopes are generally associated with faults and well-developed fracture systems close to these faults; their presence is evidence of connected pathways through which surface precipitation has percolated to depth within the last 50 years.

DOE believes that these findings do not indicate that the Yucca Mountain site would be unsuitable for development as a repository. Most of the water that infiltrates through Yucca Mountain moves very slowly through the matrix and fracture network of the rock. Isotopic data from water extracted from the rock matrix indicate that the residence time of groundwater might be as long as 10,000 years. Furthermore, after excavating more than 11 kilometers (8.4 miles) of tunnels at Yucca Mountain, DOE found that only one fracture was moist (there was no active flow of water). This observation has been confirmed in test alcoves that are not subject to the effects of drying from active ventilation.

To ensure the correct interpretation of this chemical signal, DOE instituted additional studies to determine if independent laboratories and related isotopic studies can corroborate the detection of elevated concentrations of these isotopes. Results of the validation studies to this point have not allowed firm conclusions and, thus, the evaluations continue. Nevertheless, the results of the Total System Performance Assessment described in Chapter 5 of the EIS incorporate the fast-flow data. The results show that the combination of natural and engineered barriers at Yucca Mountain would keep releases of contaminants during the first 10,000 years after closure well below the radiation limits established in 40 CFR Part 197.

Section 3.1.4.2.2 of the EIS describes the occurrence of perched water below the area of the proposed repository. The presence of perched water above the regional water table is a positive feature of the site for two reasons. First, the existence of perched water between the repository horizon and the water table indicates a barrier to flow. The perching layer possesses less matrix permeability and has a smaller fracture density than the overlying rocks. Second, the age of the perched water is thousands of years despite exhibiting a geochemical and isotopic signature that supports an interpretation of relatively rapid surface-to-depth recharge (tens to hundreds of years). In other words, the perching layer is so effective in impeding the downward flow of water that the water has aged substantially (thousands of years) in its current location. This increased residence time affords greater opportunity for diffusion and sorption of radionuclides that could be released from a breached repository.

Section 8.3 of the EIS describes the cumulative long-term impacts to groundwater from the repository and from past, present, and reasonably foreseeable future activities at the Nevada Test Site. As noted in Section 8.3.2.1.1, the estimated total potential cumulative impact (Yucca Mountain Repository plus Nevada Test Site underground testing) would be 0.17 millirem per year to the maximally exposed individual. For analytical purposes, DOE made the very conservative assumption that the radionuclide contaminants in the groundwater at the Test Site would be transported in an identical manner to those from the repository and that peak concentrations from both sources would occur at precisely the same time. The Department believes that the contribution to cumulative impacts from underground testing represents a reasonable upper bound of the actual cumulative impacts.

7.5.3 (13098)
Comment - 010227 / 0016
The lower temperature design, which is mentioned as a possibility in the SDEIS, assumes the use of an area that hasn't been studied yet. This is seen on page 2-20. Since this area has not been studied yet, there is the possibility of many fast-pathways of water movement, earthquake faults and possibly evidence of igneous activity that may not have been seen in the studies done to date.

Response
Figure 2-7 of the Supplement to the Draft EIS shows the maximum emplacement drift area that would be required for any of the various flexible-design operating modes being considered under the proposed action. Both drift areas

shown in the figure for the flexible design are slightly larger than corresponding areas shown for the repository layouts described in the Draft EIS (also shown in Figure 2-7). The only situations that would possibly require the repository to move into areas beyond the primary and lower block are those associated with the Inventory Module 1 and 2 inventories as described under cumulative impacts in Chapter 8 of the EIS. Section 8.1.2.1 describes the potential for the repository to accept the additional Inventory Module 1 and 2 waste as a reasonably foreseeable future action. However, legislative action would be required to emplace at Yucca Mountain more than the 70,000-MTHM limit specified in the NWPA. As described in the same section, should geologic blocks be needed beyond those supporting proposed action, they would be more fully characterized before their use.

Potential repository areas have been designated (should they be needed) that are outside the primary block area. Although these outside areas have not been characterized to the extent of the primary block, they are not uncharacterized. Many of the studies and evaluations performed under the Yucca Mountain characterization project have included a much broader area than what might be used for the subsurface repository. For example, faults within 100 kilometers (62 miles) of Yucca Mountain have been examined using aerial photographs and all with suspected Quaternary movement were evaluated; and the evaluations to estimate the probability of volcanic activity at Yucca Mountain looked at evidence of regional activity.

7.5.3 (13451)
Comment - 010296 / 0036
As stated by Nye County in its earlier comments on the DEIS, the impacts on water resources in Nye County were not adequately defined or assessed. The DSEIS at Section 3.1.3.1 Water Use, Evaluation of Impacts, does nothing to address these deficiencies, rather it simply restates that potential impacts would be minor and changes for impacts under the S&ER flexible design parameters would be unlikely. Buqo (1999) conducted a thorough evaluation of the impacts of the proposed repository on the water resources of the region and found that there were already significant resource injuries, constraints on water development, and a reduction in long-term productivity, loss of habitat and species, and reduced water availability. The DEIS included a brief statement recognizing that Nye County recognized these impacts and did not refute that these impacts are to be expected. However, the DEIS did not carry these impacts forward in their evaluation of direct, indirect, cumulative direct, and cumulative indirect impacts of the proposed action on the water resources of the region of influence. Rather the DEIS chose an approach that is inconsistent with both the intent and the letter of NEPA [National Environmental Policy Act]. The DSEIS perpetuates the same erroneous evaluation of impacts on water resources as that presented in the DEIS and is thus considered deficient. The DSEIS must be revised to address the impacts on the water resources of Nye County and must present evaluation of the impacts that have been identified by the County.

Response
DOE believes that the analysis of impacts to water availability presented in the EIS is adequate. Section 4.1.3.3 of the EIS estimates the amount of water the Department would need to support the repository. Sections 6.3.2.2 and 6.3.3.2 estimate water needs for each rail corridor and heavy-haul truck route, respectively. With respect to the amount of groundwater available in the areas discussed in the EIS, DOE identifies estimates of perennial yield used by the State of Nevada. Because most of the water demand associated with the Proposed Action would occur at the repository, the EIS presents a range of water availability (or perennial yield) estimates for the groundwater basin in that area.

As described in Section 4.1.3.3 of the EIS, DOE expects that the impacts to groundwater during the construction, operation and monitoring, and closure of the repository would be minor. Groundwater pumping for use at the repository would decrease groundwater availability to some extent in downgradient areas. Section 4.1.3.3 points out, however, that the quantity of groundwater that would be needed for the repository would be small compared to the quantities currently being withdrawn in downgradient areas. Therefore, the Proposed Action would have very little effect on the availability of groundwater in these downgradient areas.

7.5.3 (13470)
Comment - 010021 / 0001
Due to the volume of requests that we receive, we have not performed a detailed review of the project. However, we offer the following comments.

The community affected by this project participates in the National Flood Insurance Program (NFIP). Under this program, the Federal government makes affordable flood insurance available within participating communities. In exchange, the communities adopt certain floodplain management regulations to reduce the risk of flood damage. In support of the NFIP, FEMA has undertaken a nationwide effort to identify and map flood hazards. These flood hazards are shown on Flood Insurance Rate Maps (FIRMS), which FEMA produces for each community participating in the program. The FIRMS show identified Special Flood Hazard Areas (SFHAs). The SFHA is an area that is subject to inundation during a flood having a 1-percent chance of occurrence in a given year (also known as the base flood or 100-year flood).

Flood insurance is required for structures within SFHAs in order to protect Federal financial investments and to reduce the cost of disaster assistance. Further, the floodplain management regulations adopted by participating communities affect the construction and improvement of structures located in SFHAs. Accordingly, FEMA's concerns with the project are associated with its location in relation to identified SFHAs.

Floodplain Management Criteria for Construction in SFHAs

Our first area of concern relates to structures that may be part of the project. For new or substantially improved structures (including manufactured housing) located within SFHAs, the NFIP regulations require a community to:

- Issue permits for construction.
- Ensure that the lowest floor (including basement) is elevated to or above the base flood elevation shown on the community's FIRM.
- Ensure that any enclosed areas below the base flood elevation are used solely for access, temporary storage, or parking; are constructed of flood-resistant materials; and are properly vented to allow equalization of hydrostatic pressure in the event of a flood.
- Maintain records of permits and lowest floor elevations.

For purposes of floodplain management, a "structure" is defined as any walled and roofed building that is located principally above ground. A structure is defined as being "substantially improved" if the cost of the improvements is greater than 50 percent of the market value of the structure.

These requirements are the minimum floodplain management criteria that must be adopted by a community for participation in the NFIP. Each community that participates in the NFIP has a floodplain management ordinance that reflects these requirements. If the community's ordinance contains more restrictive criteria, the requirements of that ordinance take precedence over the minimum requirements of the NFIP.

Effects of the Project on Flood Hazards

Our second area of concern relates to the potential effects of the project on flood hazards. If the project will physically affect flood hazards shown on the FIRM, it is subject to the following:

- The project should not worsen flood hazards to adjacent properties, particularly if those properties contain insurable structures.
- FEMA has designated floodways along certain flooding sources. The floodway, which is the area that must remain free of development to ensure the safe passage of floodwaters, is shown on the FIRM. The NFIP regulations prohibit construction in the floodway unless it can be demonstrated that the construction will not cause any increase in base flood elevations.

The FIRM should accurately reflect changes to flood hazard information, such as shifts in floodplain boundaries or changes in base flood elevations, once construction is completed. If construction results in any change to the flood hazard data shown on the FIRM, the community must request a revision to the FIRM within 6 months of completion of the work. FEMA has developed an application/certification package that the community must use to request a revision. This package is available electronically on FEMA's website at www.fema.gov/mit/tsd/FRM_form.htm.

You can contact the community to obtain a copy of the current FIRM. Additional copies may be obtained for a fee from our Map Services Center; information about ordering maps is available on our website at www.fema.gov/msc.

We encourage you to work closely with the floodplain administrator for the affected community to ensure that the proposed project complies with the community's floodplain management ordinance and to ensure that the goals of the NFIP are met.

Response
DOE examined the concerns expressed in this comment in a Floodplain/Wetlands Assessment for the proposed repository at Yucca Mountain (Appendix L of the EIS). This analysis was conducted pursuant to Executive Order 11988, *Floodplain Management*, and in compliance with DOE regulations that implement this Executive Order (10 CFR Part 1022, *Compliance with Floodplain/Wetlands Environmental Review Requirements*).

7.5.3.1 Surface Hydrology/Geology

7.5.3.1 (234)
Comment - 14 comments summarized
Commenters said that neither the Draft EIS nor the Supplement to the Draft EIS considered storm runoff in Fortymile or Topopah Wash. Flooding of the Amargosa River could disrupt above-ground repository operations, transport fuel spills, oil leaks, and other toxic contaminants to Death Valley, close highways, and halt the transport of nuclear waste to Yucca Mountain. Radioactive materials transported in these floods would adversely affect Death Valley National Park, Amargosa Valley, Death Valley Junction, Tecopa, Shoshone, and all others areas downstream of Yucca Mountain and the Nevada Test Site near the Amargosa River. Some said that the Supplement should have included a stormwater flooding analysis of the proposed 0.81-square-kilometer (200-acre) storage pad near the North Portal. Commenters said that DOE ignored a recent report by scientists of the U.S. Geological Survey that showed that large storms in the 1990s had the potential to transport dissolved and particulate matter far beyond the boundary of the Nevada Test Site and the Yucca Mountain area. Some said the flooding would also affect the Timbisha Shoshone community and the land they have just been given to build their residential homes in Death Valley.

Response
Appendix L of the EIS contains a floodplain/wetlands assessment of the major washes at Yucca Mountain, including Fortymile and Topopah Washes. This analysis was conducted pursuant to Executive Order 11988, *Floodplain Management*, and in compliance with DOE's regulations that implement this Executive Order (10 CFR Part 1022, *Compliance with Floodplain/Wetlands Environmental Review Requirements*).

Section 3.1.4.1.2 of the EIS describes the flood potential at Yucca Mountain based largely on studies by the U.S. Geological Survey reported in 1984 and 1992. The new study mentioned by commenters was prepared by Glancy and Beck (DIRS 155679-1998). Glancy and Beck noted that the largest volume flood recorded along Fortymile Wash occurred in February 1969 with a peak flow of about 570 cubic meters (20,000 cubic) feet per second. Based on an eyewitness account, the entire wash (wall to wall) was filled with water about 1.2 meters (4 feet) deep (DIRS 155679-Glancy and Beck 1998). The floodplain assessment in the EIS (Appendix L) relied largely on a floodplain analysis prepared in 1984 by the U.S. Geological Survey (DIRS 102783-Squires and Young 1984). In that study, and as reported in Appendix L, peak discharge estimated along Fortymile Wash during a 100-year flood is 340 cubic meters (12,000 cubic feet) per second. During a 500-year flood, peak discharge along Fortymile Wash is estimated to be 1,600 cubic meters (58,000 cubic feet) per second. Hence, the actual flow in Fortymile Wash in 1969 as reported by Glancy and Beck was about 230 cubic meters (8,000 cubic feet) per second larger than the estimated 100-year flood, but 1,100 cubic meters (38,000 cubic feet) per second smaller than the estimated 500-year flood.

As described in Section 4.1.3.2 of the EIS, surface facilities at Yucca Mountain would be required to withstand a flood magnitude appropriate for the risk posed by the facility. That is, facilities where radioactive materials are to be managed would be sited and designed so that flooding from a 100-year, 500-year, regional maximum, or even a probable maximum flood would not adversely affect these facilities (this includes a possible spent nuclear fuel aging area that would be used to achieve lower-temperature operating conditions in the repository). Other facilities would be designed to withstand a 100-year flood. In summary, DOE believes that the largest floods that could reasonably be expected to occur at Yucca Mountain would not pose a threat to the repository, although flooding could temporarily interrupt vehicle traffic. Therefore, the probability that hazardous materials stored at the surface would be transported to the Amargosa River and eventually to Death Valley is considered very unlikely.

DOE recognizes that accidents cannot be eliminated and that there is the possibility for leaks or spills of contaminants during the construction and operation of the repository. However, the Department believes that implementing proper planning, training, and engineered controls, and adhering to the standards set by environmental regulations, can effectively reduce the probability of accidents occurring. Such actions can also reduce the severity and improve response (cleanup) should accidents occur.

7.5.3.1 (1485)
Comment - EIS001521 / 0028
Page 3-33, 3.1.4.2 [3.1.4.1.2] Yucca Mountain Surface Drainage, first paragraph--(Occurrence) Is Fortymile Wash the same as Fortymile Canyon on page 3-34, Figure 3-12 (and other figures in this volume)? Use consistent terminology.

Response
Fortymile Wash exits Fortymile Canyon just to the northeast of the Yucca Mountain site. Both are appropriate designations depending on the feature being described (wash or canyon). Although the "Fortymile Canyon" label in Figure 3-12 is in the area where the canyon begins, the corresponding text deals with drainage features (the washes). Therefore, for consistency, DOE has changed the label in Figure 3-12 to "Fortymile Wash."

7.5.3.1 (1489)
Comment - EIS001521 / 0030
Page 3-35, Table 3-9--No reference is given for regional maximum flood numbers, and why show these numbers anyway? Repository design is for a pmf [probable maximum flood] event.

Response
The source of the data in Table 3-9 is identified in footnote "a" at the bottom of the table. The Draft EIS identified a secondary reference for the information presented (that is a summary of geologic and hydrologic information developed by DOE for the EIS). The EIS now identifies the primary reference for estimates of the 100-year, 500-year, and regional maximum floods, which is Squires and Young (DIRS 102783-1984), as indicated in Figure 3-12.

Both regional and probable maximum flood levels are presented in the EIS primarily for comparison. For those reviewers more familiar with the regional maximum flood designation and how it is developed, the comparison clearly shows that the probable maximum flood value is a more conservative basis for facility design. Also, probable maximum flood values were generated only for specific areas where there would be facilities constructed under the proposed action. There has been no attempt to extrapolate these flood levels to a more drainage-wide basis. Accordingly, leaving the regional maximum flood estimates in the text and in Figure 3-12 provides the reader a better indication of a maximum, or worst-case, flood estimate over a much larger area.

7.5.3.1 (1490)
Comment - EIS001521 / 0029
Page 3-33, 3.1.4.2 [3.1.4.1.2] Yucca Mountain Surface Drainage, second paragraph (Flood Potential). Why is a "regional maximum flood" important when repository facilities are designed for a "probable maximum flood" (pmf)? Also, the definition of a regional maximum flood in the "PREDICTED FLOODS" blockout presents no relationship to time, or recurrence intervals, or flow volumes. Why include this term or does it have an analytical use?

Response
The areal extent of the "regional maximum flood," 500-year flood, and 100-year flood in Fortymile Wash and principal tributaries in the vicinity of the repository were mapped in the early 1980s by personnel with the U.S.

Geological Survey (DIRS 102783-Squires and Young 1984). The "probable maximum flood" was subsequently delineated in several areas at Yucca Mountain by Blanton (DIRS 100530-1992) using a methodology developed by the U.S. Bureau of Reclamation. Nuclear Regulatory Commission rules require mapping areas of "probable maximum flood" for sensitive facilities. Thus, the earlier work by the U.S. Geological Survey continues to be useful because it gives a broad overview of flood hazards over an extensive area. The definition of "regional maximum flood" follows usage by the U.S. Geological Survey (see EIS Section 3.1.4.1.2).

Both regional and probable maximum flood levels are presented in the EIS primarily as a means of comparison. For those reviewers more familiar with the regional maximum flood designation and how it is developed, the comparison clearly shows that the probable maximum flood is a more conservative basis for facility design. Also, probable maximum flood values were generated only for specific areas where facilities would be constructed under the Proposed Action. There was no attempt to extrapolate these flood levels to a more drainage-wide basis. Accordingly, leaving the regional maximum flood estimates in the text and in Figure 3-14 provides the reader with a better indication of a maximum, or worst-case, flood estimate over a much larger area.

7.5.3.1 (1492)
Comment - EIS001521 / 0031
Page 3-35, second paragraph--"In no case" is a rather strong statement when the estimated area of inundation for a pmf [probable maximum flood] event may come within about 300 feet of the north portal (see page 3-34, Figure 3-12). The ranges for error of estimation of volumetric estimates for a pmf event need to be very small in order to support this statement. Are they? These ranges should be included with the data.

Response
DOE has revised the EIS to include the following statement: "None of the identified flood estimates predicts water levels high enough to reach either the North or South Portal openings to the subsurface facilities, which would be at either end of the Exploratory Studies Facility tunnel shown in the figure." This change better reflects the original intent of the sentence.

The primary flood estimate studies referenced in the EIS (DIRS 100530-Blanton 1992, DIRS 108883-Bullard 1992, and DIRS 102783-Squires and Young 1984) do not include ranges of error for either the regional or probable maximum floods. However, it should be noted that DOE has developed a large map (designated YMP-98-218.3) of the flood level data presented in Figure 3-12 of the EIS. This larger map contains contour lines with a finer resolution than Figure 3-12 and shows the roughly 300 feet between the North Portal and the probable maximum flood inundation level to cover a vertical drop of 30 to 40 feet. Once outside the primary drainage channels, it would take huge volumes of water to make up this difference in elevation.

7.5.3.1 (4268)
Comment - EIS001521 / 0026
Page 3-31, 3.1.4.1 Surface Water, 3.1.4.1.1 Regional Surface Drainage, first paragraph--the term "permanent streams" should be changed to "perennial streams" for consistency with other DEIS sections. Also, the referred locations, Tecopa, Peterson Reservoir, Lower Crystal Marsh, Horseshoe Reservoir, and Ash Meadows, are not shown on page 3-32, Figure 3-11, as they should be.

Response
DOE has changed "permanent stream" to "perennial stream" in Section 3.1.4.1.1, and added Tecopa, Peterson Reservoir, Lower Crystal Marsh, Horseshoe Reservoir, and Ash Meadows to Figure 3-11.

7.5.3.1 (4269)
Comment - EIS001521 / 0027
Page 3-32, Figure 3-11--The surface drainage areas shown on the figure are not discussed in the text. Why are they important? How do they relate to each other and what is their significance to this DEIS? Were they separated by hydrologic unit characteristics? In other words, why is this figure presented?

Response
Figure 3-11 of the EIS shows the general surface-water drainage areas, or divides, in the region of Yucca Mountain. It supports the surface drainage discussion in Section 3.1.4.1.1. The cited source (DIRS 101062-Waddell 1982)

describes the subdivisions, which correspond to hydrographic areas defined by the Nevada State Engineer. The simplified figure provides an overview of the regional drainage so the text does not have to present more detail than is necessary.

7.5.3.1 (4561)
Comment - EIS001521 / 0074
Page 3-126, 3.2.2.2.3.2 Ground Water, first paragraph--Ground-water sub-basins and hydrographic areas do "not" equate (see page 3-38, Figure 3-13).

Response
DOE agrees that use of the terms subregion, basin, and section is not clear, and has changed the text to be consistent with the source document titled *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California* (DIRS 100131-D'Agnese et al. 1997), which is the main source for this information in Summary Section S.4.1.4 and Section 3.1.4.2.1 of the EIS. The flow in each subregion has clearly defined paths. For convenience the subregions were divided into basins and sections. The EIS uses these boundaries, which do not define discrete independent flow systems, for descriptive purposes only (DIRS 100131-D'Agnese et al. 1997). The groundwater flow subregion, basin, and section terminology used by D'Agnese et al. (DIRS 100131-1997) is not the same as that used by the State of Nevada for water appropriations (hydrographic areas based on topographic divides); Section 3.1.4.2.1 clarifies that distinction. DOE has added an illustration to show the relationship between the Death Valley region and subregions.

7.5.3.1 (4562)
Comment - EIS001521 / 0075
Page 3-128, Table 3-43--Hydrographic areas and ground-water basins do "not" equate.

Response
DOE agrees that the subregion, basin, and section usage is not clear, and has changed the region, subregion, basin and section terminology for groundwater flow in the text to be consistent with the source document titled *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California* (DIRS 100131-D'Agnese et al. 1997), which is the main source for this information in Summary Section S.4.1.4 and Section 3.1.4.2.1 of the EIS. The flow in each subregion has clearly defined paths. For convenience the subregions were divided into basins and sections. The EIS uses these boundaries, which do not define discrete independent flow systems, for descriptive purposes only (DIRS 100131-D'Agnese et al. 1997). The groundwater flow subregion, basin, and section terminology used by D'Agnese et al. (DIRS 100131-1997) as not the same as that used by the State of Nevada for water appropriations (hydrographic areas based on topographic divides); Section 3.1.4.2.1 clarifies that distinction. DOE has added an illustration to show the relationship between the Death Valley region and subregions.

7.5.3.1 (5494)
Comment - EIS001887 / 0162
Page 3-31; Section 3.1.4.1.1 - Regional Surface Drainage

The Draft EIS does not contain any information regarding potential discharge of contaminated groundwater that would not meet either the Nevada Water Quality Standards or the California Water Quality Standards. The Draft EIS should be reissued to include a discussion on the potential for migration of contaminants in the groundwater and possible discharge at points in Nevada and California. The question of whether this discharge would meet both Nevada's and California's Water Quality Standards should also be addressed.

Response
Chapter 3 of the EIS describes the environment that might be impacted by the proposed action; Chapters 4 and 5 describe the consequences of the proposed action. Chapter 4 addresses the consequences of constructing, operating and monitoring, and closing the repository. Chapter 5 addresses the consequences of long-term performance. As indicated in Section 4.1.3 of the EIS, the DOE believes that there is little potential for groundwater contamination during the construction, operation and monitoring, and closure phases of the proposed action. The potential for groundwater contamination is associated with the repository's long-term performance, which has been analyzed in great detail in the EIS. Estimated impacts to groundwater--and to people using that water--from the slow release of

contaminants from the repository over thousands of years are described in Chapter 5 (and in Chapter 8 with respect to cumulative impacts). The Energy Policy Act of 1992 (Public Law 102-486) directed the Environmental Protection Agency to promulgate public health and safety standards for the protection of the public from releases from radioactive materials stored or disposed of at the Yucca Mountain site. These standards have been developed and published as 40 CFR Part 197, *Environmental Radiation Protection Standards for Yucca Mountain, Nevada*. The same Act also required the Nuclear Regulatory Commission to modify its technical requirements for approving or disapproving the repository to be consistent with the Environmental Protection Agency requirements. These standards have also been established at 10 CFR Part 63, *Disposal of High-Level Radioactive Wastes in a Proposed Geological Repository at Yucca Mountain, Nevada*. These standards, mandated by law, will be used to judge the adequacy of the performance of the repository as part of the licensing process. The EIS does not in fact "analyze for" a particular standard. The EIS describes possible environmental impacts using the best available data and analysis techniques at the time of its development. In Section 5.4, the EIS does, however, compare projected groundwater contamination and corresponding exposure levels to current standards set by the Environmental Protection Agency for community drinking-water systems. These comparisons are made only as a reference point for readers of the EIS.

7.5.3.1 (5590)
Comment - EIS001887 / 0215
Page L-3; Figure L-1 -- Yucca Mountain site topography, floodplains, and potential rail corridors

This map should include the entire proposed withdrawal area, indicating the 100 and 500 year flood zones as well as rail and road corridors. Since the withdrawal area would be considered part of the Yucca Mountain repository site, the entire site and any proposed construction or improvements must be considered in the floodplain assessment.

Response
Figure L-1 of the EIS identifies potential flooding areas associated with proposed DOE actions at the Yucca Mountain site. This is consistent with requirements in 40 CFR Part 1022 to identify and assess all actions that could affect floodplains and wetlands. There are other drainage features (washes, gullies, etc.) in other portions of the withdrawal area, but repository construction and operation would not affect them. Showing the entire withdrawal area would show the location of other drainage features, but if included on the same map, it would be at the expense of showing less detail in the area where construction would take place. Also, the referenced flood studies (the results of which are shown as the flood inundation zones in Figure L-1) only included Fortymile Wash and its tributaries. That is, the same level of detail is not available for all drainage features in the withdrawal area.

With respect to rail and road corridors, the assessment in Appendix L of the EIS includes the listing of surface-water resources (including springs and riparian areas) along the various routes or corridors. In addition, the appendix now includes a listing of 100-year flood zones that would be crossed by the rail corridors based on available flood maps published by the Federal Emergency Management Agency. It does not, however, present the level of detail to include 100- or 500-year floodplain maps. DOE recognizes in the assessment (Section L.1) that a more detailed floodplain/wetlands assessment of the selected rail corridor or heavy-haul truck route would be necessary if DOE selected either transportation option.

As suggested in the Foreword to the EIS, Chapter 6, and Section 11.2.2, more detailed field surveys, government consultation, analyses, and National Environmental Policy Act reviews would be prepared if a decision was made to select a specific rail alignment within a corridor or a specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes. These would include consultations with state wildlife management agencies, the Bureau of Land Management, the Army Corps of Engineers, and other applicable government agencies. They also would include field surveys (as applicable) and more detailed assessments and analyses of wetlands and other waters; floodplains; sensitive species; and other related issues.

7.5.3.1 (5591)
Comment - EIS001887 / 0216
Page L-9; Section L.3.1.1 - Flooding

The nearest man-made structure within Fortymile Wash is the NTS road leading to Yucca Mountain. It should also be noted that, within the last decade, flooding has crossed and caused closure of U.S. Highway 95 at Fortymile Wash.

Response
The comment correctly points out that the nearest manmade structure in Fortymile Wash is the Nevada Test Site road leading to Yucca Mountain. A few roads and foundation supports for bridges that cross washes would be the only features present within the 100-year floodplain, and these would be designed to withstand the effects of potential floods. DOE has completed a flood-hazard assessment and is conducting additional analysis. Future documents will report the results of these additional studies.

7.5.3.1 (6467)
Comment - EIS001632 / 0028
Page 3-63, Section 3.1.5.1.4: This section states that "Fortymile Wash and some of its tributaries might be classified as Waters of the U.S..." It is likely that Fortymile Wash is a Water of the U.S., as well as the Amargosa River and its tributaries: Yucca Wash, Drill Hole Wash, Midway Valley Wash, Busted Butte Wash, Solitario Canyon Wash, and Crater Flat. Also, tributaries to the washes stated above may meet the Waters of the U.S. criteria, per U.S. Army Corps of Midway Valley assessment.

Response
The washes listed in the comment are tributaries to Fortymile Wash, and Fortymile Wash is a tributary to the Amargosa River. Because they are tributaries, the EIS text acknowledges that these washes might be classified as "waters of the United States." At present, there has been no formal designation of these drainage channels. Without such a designation, DOE believes that it is appropriate in the EIS to continue to indicate that these washes might be classified as waters of the United States. The Department will continue to coordinate with the Army Corps of Engineers regarding any possible future designation of these or other affected washes.

7.5.3.1 (6478)
Comment - EIS001632 / 0034
Page 4-24: Activity in drainages and washes may require a Section 404 permit if it takes place in Waters of the U.S.

Response
DOE agrees with this comment and recognizes the potential need for Section 404 permitting. Section 11.2.2 of the EIS discusses this potentially applicable requirement. As indicated in Section 11.2.2, DOE may need to obtain a permit from the U.S. Army Corps of Engineers if the repository or the transportation facilities requires the discharge of dredge or fill materials into waters of the United States.

7.5.3.1 (7377)
Comment - EIS001957 / 0017
Section 3.1.4.1, Hydrology, Surface Water, Regional Surface Drainage -- The draft EIS acknowledges that the Amargosa River system drains Yucca Mountain and the surrounding areas, and flows into the Badwater Basin in Death Valley. Nonetheless, potential environmental consequences (within Death Valley NP [National Park]) due to possible leakage of harmful radioactive constituents from the proposed repository or from transportation into this surface drainage are not considered in the draft EIS.

Response
Section 4.1.3 of the EIS addresses potential impacts to surface water and groundwater during construction, operation and monitoring, and closure of the repository. Sections 6.3.2 and 6.3.3 address potential impacts from the transport of spent nuclear fuel and high-level radioactive waste on branch rail lines and heavy-haul routes in Nevada, respectively. These sections discuss potential impacts to both surface water and groundwater along the various transportation routes evaluated. DOE believes that due to the manner in which the wastes would be managed and packaged, little potential exists for release of radioactive materials during normal operations. Sections 4.1.8 and

6.2.4 address potential impacts at the repository and during transportation, respectively, from accidents. Impacts addressed in these sections are in the form of exposures to people because that is the primary concern before cleanup actions could be completed. Consistent with this position, the transportation accidents are assumed to take place in an urban area where impacts would be greatest. Specific impacts to Death Valley National Park from accidents were not evaluated because none of the possible waste-transport routes go through the Park.

Some groundwater contamination is expected during the long-term performance of the repository as discussed in Chapter 5 of the EIS. Over the thousands of years after the repository is closed, waste containers would slowly degrade allowing a slow release of contaminants to be carried by percolating water to the groundwater. Section 3.1.4.2.1 of the EIS indicates that the primary discharge point for groundwater flowing beneath Yucca Mountain is Franklin Lake Playa in Alkali Flat. Some of the groundwater reaching this far may also by-pass the playa and continue to Death Valley. It is also recognized in the EIS that a fraction of the groundwater beneath the Amargosa Desert may flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains toward spring discharge points in Furnace Creek Wash in Death Valley. Chapter 5 of the EIS does not specifically address risks to people in Death Valley National Park from groundwater use and consumption. However, it can be clearly seen in the evaluation presented in Chapter 5 that risks would decrease with increased distance from the repository. Accordingly, impacts to Death Valley National Park would be less than the impacts predicted at the farthest locations evaluated in the EIS.

7.5.3.1 (7513)
Comment - EIS001969 / 0021
Page 3-24, first paragraph, and Page 3-33, Flood Potential.

Boulders as large as 2 meters in diameter, as well as sand, silt, and clay, are part of the alluvial deposits on these fans and stream beds. This boulder-size material has the potential for significant destructive force during the flash floods.

Response
Section 3.1.3 of the EIS has been changed to indicate that the alluvial deposits on fans and in stream beds includes boulders, cobbles, pebbles, sand, silt and clay; Section 3.1.4.1.2 has been modified to indicate that mud flows may include boulder-size material.

7.5.3.1 (8038)
Comment - EIS000391 / 0004
Mineral County believes that a number of issues are not addressed properly, not addressed adequately, or not addressed at all in the Draft EIS. These issues include but are not limited to:

Uncertainty in models and data used for site characterization and repository performance. Mineral County's flood plain map is incorrect. If this is so, how reliable is the information gathered for Yucca Mountain and other areas? The flood plain report in the DEIS is too generalized. Mineral County would like to have a detailed flood plain analysis done of Yucca Mountain and each affected county.

Response
DOE has conducted an extensive site characterization program to evaluate the proposed repository site at Yucca Mountain and has gained valuable knowledge on how the system would perform over the long-term. DOE recognizes that additional data would further define and reduce uncertainty about some aspects of the long-term performance of the repository, but also recognizes that some areas of uncertainty are inherent to the process. That is, the analysis of future periods, such as 10,000 years into the future, must deal with uncertainties that are both technical and societal. The approach DOE took in the evaluation of the long-term performance of the repository (summarized in Chapter 5 of the EIS) was to recognize the uncertainties that are important to the evaluation and to identify those it might improve with additional data. Regarding uncertainties that are the result of a data gap, the approach was to make conservative assumptions where necessary, realizing that information gained from ongoing studies might eventually support less conservative assumptions and estimates of impacts. Section 5.2.4 of the EIS discusses uncertainties associated with the long-term assessment of repository performance and the philosophy for dealing with them.

The approach and the data DOE used are scrutinized by the Nuclear Regulatory Commission and the Environmental Protection Agency, which set the standards for repository performance and the approach to predicting performance. These agencies, in turn, look to input from the international nuclear energy community and guidance from the National Academy of Sciences in prescribing methods and standards. Thus, the projections of impacts for 10,000 years represent, in the opinion of DOE, the best possible synthesis of knowledge and understanding that the Department can bring to the solution of disposing of spent nuclear fuel and high-level radioactive waste.

Regarding the Mineral County floodplain map being incorrect, the EIS does not discuss Mineral County floodplain issues because neither the proposed repository nor any of the candidate transportation routes would be in Mineral County. However, DOE can address the general concern expressed by the comment. The floodplain/wetlands assessment in Appendix L of the EIS examines and compares the effects of the potential construction of a branch rail line or an intermodal transfer station with its associated route for heavy-haul trucks on floodplains and wetlands in the vicinity of Yucca Mountain and along the candidate routes. DOE did not evaluate potential effects along existing routes because the design of those roads should meet the 100-year floodplain design specifications. Section L.1 recognizes, however, that a more detailed floodplain/wetlands assessment of the selected rail corridor would be necessary after any decision on a specific corridor.

In addition, and as suggested in the Foreword to the EIS, Chapter 6, and Section 11.2.2 (subsection on Compliance with Floodplain/Wetlands Environmental Review Requirements) DOE would perform detailed field surveys, additional government consultation, analyses, and National Environmental Policy Act reviews if a decision was made to select a specific rail alignment within a corridor or a specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes. These would include consultations with state wildlife management agencies, the Bureau of Land Management, the U.S. Army Corps of Engineers, and other applicable government agencies. They also would include field surveys (as applicable) and more detailed assessments and analyses of wetlands and other waters; floodplains; sensitive species; and other related issues.

7.5.3.1 (8155)
Comment - EIS000817 / 0083
P. 3-35 & 36. The U.S. Geological Survey 1997 has a new methodology that could result in larger 100-year flood limits. And there are differences of opinion on the complex groundwater systems. So it comes down to -- which experts do you choose to believe? And at which point in time do you say -- "No further studies -- we know what we know is right?" I think "never" is the answer. You just don't really know for sure any of this. It's all prediction, assumption, uncertainty, especially with global warming and climate change very evident already. Floods and droughts will change water routes -- droughts could actually open up fissures and fractures to wider openings I would expect. You can't predict the weather long term any more than our local weather man I suspect -- you don't know for sure.

Response
This comment refers to statements in Section 3.1.4.1.2 of the EIS on a revised U.S. Geological Survey method for calculating peak flood discharges in the southwestern United States. This method applies only to 2-, 5-, 10-, 25-, 50-, and 100-year floods and not to the 500-year flood or the larger regional maximum flood or probable maximum flood. Moreover, DOE has not applied the revised method in the Yucca Mountain area because of inadequate records at gauging stations (DIRS 151945-CRWMS M&O 2000). Flood potential studies do not attempt to predict flood events. Rather, they use past stream discharge records to estimate statistically the probable recurrence frequency of peak discharges and areas of inundation. This is a standard engineering technique to enable the safe design of facilities in flood-prone areas, and is not unique to the Yucca Mountain Site Characterization Project. The Nuclear Regulatory Commission requires the calculation of probable maximum flood for sensitive nuclear facilities.

7.5.3.1 (8888)
Comment - EIS001834 / 0029
The DEIS also notes that the DOE will use controls to limit surface water contamination, but the DEIS does not outline the impacts that could occur if DOE's controls fail. It is unacceptable to state categorically that there will be no impacts because controls are in place. If that were true, the word "accident" would not be in our vocabulary.

Response
DOE agrees that there is a potential for accidents. However, the Department feels that proper planning and training, in addition to engineered controls and adherence to standards set by environmental regulations, can effectively reduce the probability of their occurring. Such actions can also reduce the severity and improve response actions (cleanup) should accidents occur, thereby minimizing environmental impacts.

DOE also agrees that it would be improper to state categorically that there would be no impacts to surface water. Section 4.1.3.2 of the EIS discusses potential impacts to surface water from the Proposed Action. The discussion identifies activities that could involve discharges of water to the surface and the types of materials that could cause surface-water contamination if released. In addition, the discussion describes features of the site and proposed activities that would tend to minimize the potential for releases or the impacts from releases if they occurred. In addition to the planning, training, controls, and regulatory compliance actions described above, the following features would tend to minimize the potential for impacts to surface waters:

1. Natural surface water is seldom present at the site to receive and spread contamination.

2. The types and nature of hazardous materials that would be present at the site to support the Proposed Action would be limited in variety and quantity, with handling and storage in accordance with regulatory requirements.

3. The spent nuclear fuel and high-level radioactive waste at the site would be in sealed, high-integrity containers unless they were inside facilities.

4. DOE would build facilities in the Restricted Area (where it would manage radioactive materials) to withstand the probable maximum flood.

7.5.3.1 (10923)
Comment - EIS000244 / 0008
The surface water is almost nonexistent except during some of the storms there because of what little surface water there is. There is sometimes six inches of rain, sometimes ten inches of rain. And I don’t know the evapotranspiration there, but I know miles to the south of Ward Valley was 105 inches a year. So the potential of evaporation is ten times more than the rainfall or more.

Response
The commenter apparently is referring to Sections 3.1.2.2 and 3.1.4 of the Draft EIS regarding rainfall amounts and potential evaporation rates. Winter rainfall can exceed 5 centimeters (2 inches) daily in the Yucca Mountain region, and summer thunderstorms can exceed 2.5 centimeters (1 inch) in a matter of hours. These statements are consistent with the commenter’s observation. Section 3.1.4 describes that the, potential evaporation is about 170 centimeters (66.9 inches) per year, which far exceeds the annual precipitation of 10-25 centimeters (3.9-9.8 inches) per year in the region and is in general agreement with the commenter’s observation.

7.5.3.1 (11001)
Comment - EIS000623 / 0002
On [page] 6-62, it mentions that there’s only one spring. Well, I found that not to be true. Looking on any of the maps that we have here, and there is an additional one that is below this, just so that it is on record for the water and maybe not just a spring but because wherever water comes from the ground there is one flowing well, there are six additional springs, there are six borderline springs. And I’d also like to mention of this if there ever was a problem, the old pluvial lakes that existed out here, a lot of them drained into Crescent Valley. Grass Valley and Carico Lake Valley have drainages that come into here. All this water flows from there to here. So if anything in between here and there is happening, it is unretrievable, there would be problems. Also there are three creeks that run year round that would be near this or through the proposed rail route, Steiner, Skull, Callahan, and also I might add a fourth one, Indian Creek as well, which is just right up over here. That is one of my main concerns, as well as our hot spring system that we have. Now, there are two private residences with thermal springs, and at the Hot Springs Point, the spring is undeveloped, and a lot of animal life in this valley go there for watering and for food, as well as, I might add, the Loudens, on their developed spring, and I have seen this personally, many types of migratory fowl and animals come through there as well.

Response
The EIS identifies one spring as being inside the 0.4-kilometer (0.25-mile) corridor in which the Carlin branch line would be located. However, Table 6-25 of the EIS also identifies 10 additional springs that are outside the corridor, but within 1 kilometer (0.62 mile). The table also shows five streams or riparian areas within the corridor and two others within 1 kilometer. Names and locations of specific surface-water resources summarized in Table 6-25 are shown in Table 3-37. Without knowing what areas on the map the commenter pointed to, DOE cannot determine whether or not the commenter is aware of additional surface-water resources that should be identified in the EIS. Table 3-37 lists Skull Creek as being in the corridor and the reference to this information (DIRS 104593-CRWMS M&O 1999) shows Steiner Creek being in the corridor of a Carlin line variation (see Figure 3-23). Callaghan and Indian Creeks were not found in the reference, but other creeks in the area with different names were identified.

Section 6.3.2.2.2 of the EIS discusses impacts to wildlife from the construction and operation of a branch rail line in the Carlin Corridor. DOE believes the potential for contaminants to be released to water resources during construction or operation of a branch rail line would be minor, as discussed in Section 6.3.2.1.

7.5.3.1 (12175)
Comment - EIS001622 / 0037
Page 3-35, Table 3-10. The total dissolved solids values listed in the table only range from 45 to 122 mg/L. However, the bicarbonate values alone are listed as ranging from 32 to 340 mg/L. Given the data presented in the table, TDS values should range from 51.5 to 516 mg/L. This discrepancy in the data table needs correction.

Response
The comment is correct. The values listed in Table 3-10 for total dissolved solids are not appropriate considering the other values listed in the table. An investigation of the problem found that the sampling sites represented by the values for total dissolved solids are a subset of the sampling sites represented by the other numbers in the table. DOE has corrected Table 3-10, and each data-range is from the same set of sampling locations. For example, the values for total dissolved solids remain the same, but the bicarbonate values range between 32 and 109 milligrams per liter.

7.5.3.1 (12668)
Comment - EIS000206 / 0009
Question that is not answered by DOE: the geology underground has proven difficult to model; recent data at the adjoining NTS have demonstrated far faster migration of plutonium underground than DOE scientists have predicted.

The important of question of water seepage through the site remains open; higher than expected levels of Chlorine 36 at the repository level can only be explained by water penetration from the surface in the last few decades.

Response
Section 3.1.4.2.2 of the EIS describes recent findings on the Nevada Test Site concerning the migration of plutonium. The small amount of plutonium detected in groundwater farther than expected from its source (a 1968 underground nuclear test) was apparently associated with the movement of colloids (very small particles). These findings suggest that radionuclides that are attached to colloids move faster than dissolved radionuclides because the colloids can travel in the faster parts of the flow paths, and sorb less onto host rocks than do dissolved radionuclides. Thus, the potential for faster movement of colloids becomes particularly important for radionuclides with high sorption, such as plutonium. Analysis of the long-term performance of the proposed repository incorporates the potential for plutonium to move with colloids (see Chapter 5 and Appendix I of the EIS). As described in Section I.3.1, DOE left plutonium species (specifically plutonium-239 and -242) in the model in spite of high sorption rates because of the large inventory that would be in the repository and the potential for colloidal transport. Consistent with this, the summary of modeling results in Section 5.4.2 attributes projected impacts from plutonium migration to colloidal transport, not transport as a dissolved element. The modeling of plutonium transport on colloids began with parameters derived from data obtained on the Nevada Test Site. The modeling, however, included input parameters that were above and below those derived from the Test Site data because the specifics of colloid properties and transport are not adequately known.

Section 3.1.4.2.2 of the EIS discusses the results of chlorine-36 studies. Water in limited parts of the Exploratory Studies Facility has apparently infiltrated from the surface to the waste-emplacement horizon in about 50 years. Water movement through rock fractures at the site is a key component of infiltration. This infiltration occurs much quicker along fractures than through the rock matrix. Chapter 5 and Appendix I of the EIS describe the models DOE used to analyze the long-term performance of the repository, including a model of flow through the unsaturated zone that simulates the movement of water through Yucca Mountain. As described in Section I.2.2 of the EIS, this model incorporates several different rock types to simulate different rates of water movement. It uses annual infiltration rates based on three different climates that could occur over thousands and hundreds of thousands of years (the current climate is the driest of the three). The quantity and location of water moving through the underground repository is a critical factor in analyzing long-term performance, and DOE would like to reduce the amount of uncertainty associated with the data being used in the model simulations.

7.5.3.2 Subsurface Hydrology/Geology

7.5.3.2 (2)
Comment - 13 comments summarized
Commenters were concerned that the repository would adversely affect Death Valley National Park. Some said that the repository would release radioactive contaminants into the groundwater which would threaten springs, surface water, and threatened and endangered species in Death Valley National Park and the Devils Hole Protective Withdrawal. Some noted that the springs in Furnace Creek Wash supply domestic and commercial water to Furnace Creek and maintain sensitive wildlife habitat. Others wanted to know how much of the spring flow in Death Valley was from the volcanic aquifer beneath Yucca Mountain.

Response
As described in Chapter 5 of the EIS, analyses of long-term performance of the repository have shown that releases of contaminants from the repository during the 10,000-year compliance period would be very small and well below the standards contained in 40 CFR Part 197. Measurable adverse impacts to humans and the environment would not be expected in any areas south of the repository, including Death Valley.

As described in Section 3.1.4 of the EIS, DOE has conducted an extensive program to characterize the direction and nature of groundwater flow and transport from the Yucca Mountain site. The general path of water that percolates through Yucca Mountain is southward toward the town of Amargosa Valley, then beneath the area around Death Valley Junction in the southern Amargosa Desert. The groundwater beneath Yucca Mountain merges and mixes with groundwater beneath Fortymile Wash. This groundwater then flows toward, and mixes with, the large groundwater reservoir in the Amargosa Desert. The natural discharge point of this groundwater occurs farther south in Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume may flow south toward Tecopa into the southern Death Valley area. A fraction of the groundwater may flow through fractures in the relatively impermeable Precambrian rocks at the southeastern end of the Funeral Mountains toward springs in the Furnace Creek area of Death Valley. Potentiometric data indicate that a divide could exist in the Funeral Mountains between the Amargosa Desert and Death Valley. This divide would limit discharge from the shallow flow system, but would not necessarily affect the flow from the deeper carbonate aquifer that may contribute discharge to springs in the Furnace Creek area (DIRS 100465-Luckey et al. 1996).

Geochemical, isotopic, and temperature data indicate that water discharging from springs in the Furnace Creek area is a mixture of water from basin-fill aquifers in the northwestern Amargosa Desert and from deeper flow in the regional carbonate aquifer (DIRS 101167-Winograd and Thordarson 1975). Groundwater in the northwestern Amargosa Desert originates in Oasis Valley and from the eastern slope of the Funeral Mountains, both of which are west of the flow paths that extend southward from Yucca Mountain. Even if part of the flow from Yucca Mountain mixes with the carbonate pathway that supplies the springs in Furnace Creek, it would be too little to noticeably affect the water quality of these springs. Considering the small amount of water that would infiltrate though the repository footprint compared to total amount of water flowing through the basin (approximately 0.2 percent or less), and the large distances involved [more than 60 kilometers (37 miles) from the source], any component of flow from Yucca Mountain that traveled this long and complicated flow path would be diluted to such an extent that it would be undetectable.

Groundwater that infiltrates through Yucca Mountain does not discharge at either the Devils Hole Protective Withdrawal or in Ash Meadows. The elevation of the water table in the Devils Hole/Ash Meadows area is about 64 meters (210 feet) higher than the water table in the Amargosa Desert to the west and south. This elevation decline indicates that groundwater from the carbonate rocks beneath the Devils Hole Hills flows westward across Ash Meadows toward the Amargosa Desert, not the other way around. Therefore, potential contaminants from Yucca Mountain could not discharge at springs in Devils Hole and Ash Meadows nor contaminate the aquifer.

Based on the foregoing discussion, and on analyses reported in the EIS, the ecosystem of Death Valley National Park would not be effected by the construction, operation, or closure of a repository at Yucca Mountain.

7.5.3.2 (8)
Comment - 16 comments summarized
Commenters said that the EIS inadequately described the relationships among the lower carbonate aquifer, the overlying volcanic units, and the alluvial units in valley areas. Because of data uncertainties, commenters said that DOE should acquire more data, develop better models, and describe a groundwater monitoring program. Commenters said that most groundwater studies were done on a regional scale and that apparent hydraulic-conductivity measurements are not very reliable at this scale. These commenters said that DOE should conduct additional hydraulic analysis of units near the repository and in downgradient areas based on multiwell draw-down tests, and provide additional description of the hydrologic data that have been gathered at Yucca Mountain. Commenters noted that only one well penetrates the deep carbonate aquifer. This was not considered to be adequate for determining the direction of groundwater flow and hydraulic conductivity, or to support the conclusion in the EIS that the entire carbonate aquifer has an upward gradient. Some said additional studies should be conducted on the fracture pathways leading to the carbonate aquifer. Given the many uncertainties about the hydrology of the region, commenters said that DOE needs much more information to conclude that the repository would operate as planned. Others noted that the cause of the large hydrologic gradient immediately north of Yucca Mountain has not been determined and that uncertainties exist about the pattern of groundwater flow beneath Pahute Mesa and Fortymile Wash, and the relationship of this flow to groundwater movement beneath Yucca Mountain. Because DOE acknowledges that data uncertainties exist, DOE should also acknowledge uncertainty regarding the direction of groundwater flow.

Response
DOE believes that it has sufficient information and understanding of the hydrologic setting to make an adequate determination of the potential environmental impacts from the Proposed Action. DOE, the U.S. Geological Survey, and others have been evaluating and assessing the hydrologic setting and associated characteristics at the Yucca Mountain site and nearby region for more than two decades. During this time DOE has modified its program to reflect new information and assessments and to accommodate reviews by independent parties, both internal and external to the Department. Nevertheless, DOE recognizes that additional information would refine its understanding of the regional groundwater flow system, and would reduce uncertainties associated with flow and transport in the alluvial, volcanic, and carbonate aquifers.

To obtain additional information, DOE has supported Nye County, with it's program (called the *Early Warning Drilling Program*) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the ongoing site characterization program (and possible performance confirmation program (which is described below) could be used in conjunction with that of the Early Warning Drilling Program to refine the DOE understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information, which is described in Section 3.1.4.2.1 of the EIS.

In addition, DOE has installed a series of test wells along the groundwater flow path between the Yucca Mountain site and the Town of Amargosa Valley as part of an alluvial testing complex. The objective of this program is to better characterize the alluvial deposits beneath Fortymile Wash along the east side of Yucca Mountain. Single- and multi-well tracer tests have begun and the results thus far have strengthened the basis of the site-scale saturated flow and transport model. This program is described in Section 3.1.4.2.1 of the EIS.

If the site were approved, DOE would continue to implement a "performance confirmation program," elements of which could address the hydrologic system. The purpose of this program is to evaluate the adequacy of the information used to demonstrate compliance with performance objectives. The performance confirmation program would continue through closure of the repository (possibly as long as 300 or more years after the end of emplacement). Data from this monitoring could offer a means to further understanding of the hydrologic system and reduce uncertainties.

Section 3.1.4.2.2 of the EIS refers to the large hydraulic gradient north of the site. An expert elicitation panel (DIRS 100353-CRWMS M&O 1998) addressed this feature and narrowed its likely cause to two theories: (1) flow through the upper volcanic confining unit or (2) semiperched water. The consensus of the panel favored the perched-water theory. Whatever the cause, the experts were in agreement that the probability of any large transient change in the configuration of this gradient is extremely low (DIRS 100353-CRWMS M&O 1998).

The understanding of the flow system and hydraulic relationships of the lower carbonate aquifer are based not only on data from well UE 25p #1 at Yucca Mountain, but on a large body of regional hydrologic and chemical evidence collected over the past 40 years. In addition to the one well (UE 25p #1) that penetrated the carbonate aquifer at Yucca Mountain, another well (NC-EWDP-2DB) along the potential flow path in Fortymile Wash has penetrated the carbonate aquifer and an upward hydraulic gradient was present. Well NC-EWDP-2DB, along with six additional planned wells, will help characterize the carbonate aquifer system near Yucca Mountain as part of the Nye County Early Warning Drilling Program. Four other wells at Yucca Mountain, as reported by Luckey et al. (DIRS 100465-1996), are believed to indicate the potentiometric level in the carbonate aquifer. Elsewhere in the general area, particularly at the southern end of the Nevada Test Site and eastward from the springs in Ash Meadows, the hydraulic relationship between the lower carbonate aquifer and overlying units is well understood (DIRS 101167-Winograd and Thordarson 1975). The very presence of the springs in Ash Meadows demonstrates the fact of an upward hydraulic gradient in the lower carbonate aquifer. Because the lower carbonate aquifer is buried by some 6,000 feet of unconsolidated deposits in the Amargosa Desert west of the springs in Ash Meadows, no wells have been drilled to this aquifer at this location. Claassen (DIRS 101125, 1985) presents hydraulic and hydrochemical evidence of subsurface discharge from the lower carbonate aquifer to the alluvial fill of the Amargosa Desert to the west of Rock Valley Wash. In addition, several investigators have concluded from hydrologic, chemical, and isotopic evidence that the lower carbonate aquifer is the source of the large springs in Furnace Creek Wash (Death Valley). DOE believes that there is sufficient information to make an informed determination about potential impacts from a repository at Yucca Mountain.

DOE would design and implement a postclosure monitoring program in compliance with the Nuclear Regulatory Commission regulations (10 CFR Part 63). Before closure, DOE would submit an application for a license amendment to the Nuclear Regulatory Commission for review and approval. The application would include, among other items:

1. An update of the assessment of the performance of the repository for the period after closure;

2. A description of the postclosure monitoring program;

3. A detailed description of measures to regulate or prevent activities that could impair the long-term isolation of the waste, and to preserve relevant information for use by future generations.

The application also would describe DOE's proposal for continued oversight to prevent any activity at the site that would pose an unreasonable risk of breaching the repository's engineered barriers, or increase the exposure of individual members of the public to radiation beyond limits allowed by the Nuclear Regulatory Commission. DOE has modified Chapter 9 of the EIS to include the types of monitoring and other institutional controls that would be contemplated. The Department would develop the details of this program during the consideration of the license amendment for closure. This would allow the Department to take advantage of new technological information, as appropriate.

7.5.3.2 (111)
Comment - 23 comments summarized
Commenters said that many studies have demonstrated that fractures at Yucca Mountain provide fast paths for surface water to penetrate to the waste-emplacement horizon and then to the saturated zone. Some noted that water samples collected along fractures and from the exploratory studies facility contain elevated amounts of chlorine-36 and tritium. The source of the chlorine-36 and tritium is atmospheric testing of nuclear weapons during the past 50 years in the Pacific and on the Nevada Test Site. This discovery contradicts earlier models of the unsaturated zone that depict water moving very slowly through pores in the rock. Some commenters said that contaminated groundwater could reach humans through water wells in less than 1,000 years, thereby disqualifying the site because it meets the conditions of 10 CFR 960.4-2-1. Others said that based on these findings, it is clear that the expected performance of the repository would result in significant radionuclide contamination of groundwater and, ultimately, surface waters downgradient from the site.

Response
As part of its site characterization activities, DOE has conducted a variety of investigations into the nature of water falling as precipitation on Yucca Mountain and passing through the unsaturated zone to the groundwater beneath. One such study has been to quantify the concentrations of certain radioisotopes in the Exploratory Studies Facility. Isotopes, such as chlorine-36 and tritium, which occur naturally and as a byproduct of atmospheric nuclear weapons testing, respectively, serve as indicators of the rate of flow through the unsaturated zone.

Results from preliminary studies have identified these isotopes in concentrations that tend to suggest that there are connected pathways through which surface precipitation has percolated to the repository horizon within the last 50 years. However, these isotopes have been found at locations that are generally associated with known, through-going faults and well-developed fracture systems close to the faults at the proposed repository horizon.

To ensure the correct interpretation of this chemical signal, DOE instituted additional studies to determine if independent laboratories and related isotopic studies can corroborate the detection of elevated concentrations of these radioisotopes. Results of the validation studies to this point have not allowed firm conclusions and, thus, the evaluations continue.

DOE believes that these findings do not indicate that the Yucca Mountain site should be declared unsuitable for development as a repository. Most of the water that infiltrates Yucca Mountain moves slowly through the matrix and fracture network of the rock, and isotopic data from water extracted from the rock matrix indicates that residence times are generally several thousand to as long as 10,000 years. Furthermore, after excavating more than 11 kilometers (8.4 miles) of tunnels at Yucca Mountain, DOE determined that only one fracture was moist (there was no active flow of water). This observation has been confirmed in test alcoves that are not subject to the effects of drying from active ventilation.

Nevertheless, the total system performance assessment incorporates the more conservative water movement data as well as information from other water infiltration and associated hydrogeological studies. As a result of this evaluation, DOE would not expect the repository (combination of natural and engineered barriers) to exceed the prescribed radiation exposure limits during the first 10,000 years after closure.

With regard to the expected long-term performance of the repository, modeling described in Chapter 5 shows that the combination of natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials from the repository to very small amounts during the first 10,000 years after permanent closure. This would comply with the limits specified by the Environmental Protection Agency in 40 CFR Part 197, *Environmental Radiation Protection Standards for Yucca Mountain, Nevada*.

With respect to disqualifying conditions at Yucca Mountain, explicit disqualifiers were included in DOE's 1984 site suitability guidelines (10 CFR Part 960) in order to guide the agency's assessment of multiple sites under consideration for repository development. At that time, failure to meet the qualifying condition of any guideline was a basis for disqualifying a site. Under the Nuclear Waste Policy Act, as amended in 1987, Congress directed DOE to focus only on Yucca Mountain and directed the Environmental Protection Agency and the Nuclear Regulatory Commission to promulgate standards to protect public health and safety (40 CFR Part 197 and 10 CFR Part 63).

Failure to meet the Environmental Protection Agency standards or the Nuclear Regulatory Commission criteria for licensing would disqualify the Yucca Mountain site.

In 1996, DOE published proposed amendments to its guidelines (10 CFR Part 960) to reflect the prevailing scientific view on how to evaluate the suitability of the Yucca Mountain site for the development of a nuclear waste repository (61 *FR* 66158). Because Congress had by this time required DOE to focus only on Yucca Mountain, DOE's proposed amendments dealt with provisions of the guidelines that were applicable to the site recommendation stage. In November 1999, DOE revised its 1996 proposal (64 *FR* 67054) to focus on the criteria and methodology to be used for evaluating geological and other related aspects of the Yucca Mountain site.

In 1987, amendments to the Nuclear Waste Policy Act specified Yucca Mountain as the only site DOE was to characterize. For this reason, and given advancements in site characterization, DOE proposed in 1996 to clarify and focus its 1984 guidelines to apply only to the Yucca Mountain site, but never made the revised guidelines final. In 1999, DOE proposed to further revise the terms of the guidelines (draft 10 CFR Part 963), based on three primary reasons:

1. To address comments that criticized the omission of essential details of the criteria and methodology for evaluating the suitability of the Yucca Mountain site.

2. To update the criteria and methodology for assessing site suitability based on the most current technical and scientific understanding of the performance of a repository at the Yucca Mountain site, as reflected in the DOE report, *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998a).

3. To be consistent with the then-proposed site-specific licensing criteria for the Yucca Mountain site issued by the Nuclear Regulatory Commission (the Commission has since finalized these criteria at 10 CFR Part 63), and the then-proposed site-specific radiation protection standards issued by the Environmental Protection Agency (finalized at 40 CFR Part 197).

In 2001, DOE finalized its guidelines to evaluate the suitability of the Yucca Mountain site for development as a geologic repository (10 CFR Part 963).

7.5.3.2 (228)
Comment - 91 comments summarized
Commenters said that Yucca Mountain is not a stable or safe place for a geologic repository because the region is prone to faulting, earthquakes, and volcanic activity. Commenters pointed out that Nevada is the third-most seismically active state in the nation and that the 1992 earthquake at Little Skull Mountain severely damaged DOE buildings near Yucca Mountain. Others cited recent studies in Science Magazine that the earth's crust at the site is moving faster than previously estimated. This suggests that DOE underestimated the volcanic and seismic hazards at Yucca Mountain, including evidence for a shallow magma chamber beneath Yucca Mountain which increases the likelihood for a volcanic eruption.

Many commenters said that DOE did not examine these subjects in the EIS, or examined them inadequately, or disagreed with DOE's assessment of the impacts that these geologic hazards pose on the short- and long-term performance of the repository. Many others questioned how DOE could be sure of the estimated impacts from these hazards considering the 10,000-plus years that the repository is required to operate safely.

Response
Based on the results of analyses reported in Chapter 5 of the EIS concerning the long-term performance of the repository, which considered the effects of future earthquakes and volcanic activity, DOE believes that a repository at Yucca Mountain would result in small short- and long-term environmental impacts. Concerning the adequacy of the descriptions and analyses in the EIS, Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes the likely impacts from accidents caused by earthquakes during operation of the repository. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. Some factual changes and clarifications that have been included in the Final EIS, and DOE believes

that the EIS adequately describes and analyzes on the geology, geologic hazards, and the effects of these hazards on the repository.

As discussed in Section 3.1.3.3 of the EIS, DOE has been monitoring seismic activity and studying the geologic structure at and near Yucca Mountain since 1978. Using the results of these and other studies conducted in the Region, along with input from panels of recognized experts on seismic risks and hazards, surface facilities at the repository would be designed to withstand the effects of earthquakes that might occur during the lifetime of the facilities. The seismic design requirements for the repository specify that structures, systems, and components that are important to safety must be designed to withstand horizontal ground motion with an annual frequency of occurrence of once in 10,000 years. This is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

The 1992 earthquake at Little Skull Mountain 20 kilometers (12 miles) southeast of Yucca Mountain was the largest recorded earthquake within 50 kilometers (31 miles) of the proposed site of the repository. This earthquake, with a Richter magnitude of 5.6, did not damage facilities or structures at Yucca Mountain. It did, however, cause about $100,000 damage to buildings at the Field Operations Center in Jackass Flats about 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility). These old buildings were not constructed to the seismic design specifications that would be used for surface facilities at Yucca Mountain.

The State of Nevada ranks third, behind Alaska and California, in seismic activity. Nevada's reputation as a seismically active state comes from major historic earthquakes in western and central Nevada with magnitudes of 7 or more on the Richter scale. This seismic belt may be an extension into Nevada of the Death Valley-Furnace Creek fault system in southeastern California. The average frequency of earthquakes of magnitude 6.0 to 6.9 in western Nevada has been about one every 10 years; earthquakes of magnitude 7 and greater average about one every 27 years. Yucca Mountain does not lie within this highly active seismic belt. Nevertheless, DOE estimated the impacts from extremely large and unlikely seismic events ("beyond design-basis") that could cause the waste-handling building to collapse and damage the pressurized-water reactor fuel assemblies. DOE concluded that the impacts from such an extreme event would be small because of the physical form of the fuel assemblies, protection by the building rubble, and the long distance to the nearest population.

The study reported in *Science* was prepared by Wernicke et al. (DIRS 103485-1998) and is discussed in Section 3.1.3.3 of the EIS. This study was based on measurements using a Global Positioning System over the period from 1991 to 1997 at five stations in the Yucca Mountain area. The authors claim that the crustal strain rates in the Yucca Mountain region are at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. If higher strain rates exist, the authors suggest that the volcanic and seismic hazards at Yucca Mountain could be underestimated on the basis of the long-term geologic record.

In May 1998, scientists from the U.S. Geological Survey resurveyed the area using a network of 14 geodetic stations that was originally installed in 1983 (DIRS 103458-Savage, Svarc, and Prescott 1998). Two of the 14 stations were used by Wernicke et al. (DIRS 103458-1998) in their study. Based on the greater number of stations, the longer survey period (1983 to 1998), and the removal of the effects of the June 1992 Little Skull Mountain earthquake, the U.S. Geological Survey concluded that the strain rate in the Yucca Mountain region is about an order of magnitude lower than that reported by Wernicke et al. (DIRS 103485-1998). The results of the U.S. Geological Survey study are consistent with a large body of geological data that has been collected in the Yucca Mountain region during the past two decades.

Wernicke et al. (DIRS 103485-1998) also speculated that the high strain accumulation across the Yucca Mountain area could be driven by magmatic inflation at depth. They pointed to an early seismic study that hinted at the presence of a low-velocity zone beneath Crater Flat that could be consistent with basaltic magma (DIRS 106447-Oliver, Ponce, and Hunter 1995). A subsequent study demonstrated rather conclusively that there is no low-velocity zone under Crater Flat or Yucca Mountain that would suggest a major volcanic hazard (DIRS 105358-Biasi 1996).

Based on the subsequent investigations by the U.S. Geological Survey described above, DOE does not concur with the results reported by Wernicke et al. (DIRS 103485-1998). DOE is nevertheless continuing to monitor crustal strain in the Yucca Mountain region through a cooperative agreement with the University of Nevada. Dr. Wernicke, the principal investigator of this study, recently estimated in a quarterly report to the Yucca Mountain Project that conclusions should be available in 2002.

DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. Section 5.2.4 of the EIS describes how DOE dealt with these uncertainties. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Nuclear Regulatory Commission indicates that absolute proof is not to be had in the ordinary sense of the word (see 10 CFR Part 63), and the Environmental Protection Agency finds that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance (see 40 CFR Part 197).

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to assessing the long-term performance of the repository addresses and compensates for important uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

The proposed waste emplacement horizon at Yucca Mountain would be excavated in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have much less affect on subsurface facilities than surface facilities. Inspection of tunnels in the Yucca Mountain area after earthquakes has revealed little evidence of disturbance. Furthermore, the proposed waste emplacement horizon is not near faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide releases. Postemplacement seismic activity at Yucca Mountain would probably be along existing fault planes.

As described in Section 3.1.3 of the EIS, the most recent volcanic eruption in the area occurred between 70,000 and 90,000 years ago about 10 miles south of the Yucca Mountain site. The next-youngest eruptions were in Crater Flat west of Yucca Mountain where four northeast-trending cinder cones developed about 1 million years ago. A panel of experts examined the data, models, and related uncertainties, and concluded that the probability of a volcanic dike disrupting the repository during the first 10,000 years after closure is 1 in 7,000 (one chance in 70 million per year). This estimate was recalculated in Section 3.1.3.1 of the Final EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRMS M&O 2000). Although extremely unlikely, a volcanic eruption through the repository could spread ash and entrained waste into the atmosphere and magma into the waste-emplacement drifts. DOE estimated the potential impacts to the nearest population, conservatively assuming the direction and speed of wind transport of an ash plume, and determined that the impacts to public health and safety would be very small. DOE also determined that magma flowing into the waste-emplacement drifts would have minimal impacts on the long-term performance of the repository.

As described in Chapter 5, during the first 10,000 years after closure of the repository, earthquake-induced shaking could dislodge rocks from the roof of the emplacement drifts. The likelihood of falling rocks splitting open a waste package is essentially zero because waste packages would be protected by titanium drip shields. Even if a drip shield were ruptured by falling rocks, the force and impact would be absorbed by the drip shield and not transferred completely to the waste package. Furthermore, the metal walls of the waste package itself would be designed to withstand the impact from falling rocks.

7.5.3.2 (229)
Comment - 24 comments summarized
Commenters said that groundwater could rise sufficiently high to flood the underground repository. Some pointed to reports that theorized that groundwater had risen to elevations in the past that could inundate the proposed waste-emplacement horizon. Others said that DOE did not consider these studies adequately. Some pointed out that DOE is funding additional work on this topic through the University of Nevada, Las Vegas, and that the EIS should not be completed until this work is done. Still others said that DOE should have examined the impacts to the long-term performance of the repository if an extreme climatic change caused groundwater to enter the underground repository. Reasons cited for rises of the water table included, in addition to climatic changes, earthquakes and volcanic eruptions.

Response
Section 3.1.4.2.2 of the EIS discusses the views of several investigators concerning fluctuations in the elevation of the water table that are in opposition to DOE's views regarding that subject. These investigators have stated that the water table at Yucca Mountain has risen in the past to elevations that are higher than the proposed waste-emplacement horizon beneath Yucca Mountain. Based on the results of these and other analyses reported in Section 3.1.4.2.2, DOE has concluded that no credible combination of future climate change, earthquakes, and volcanic eruptions could raise the water table sufficiently high to inundate the waste emplacement horizon.

The water table is about 750 meters (2,500 feet) below the crest of Yucca Mountain. Under the Proposed Action, DOE would emplace the waste 160 to 400 meters (525 to 1,300 feet) above the water table. Section 3.1.4.2.2 of the EIS describes evidence that the elevation of the water table has fluctuated over the past million years. Scientists working on the Yucca Mountain Project have estimated that the water table could rise by 50 to 130 meters (160 to 430 feet) under extremely wet climatic conditions. The regional aquifer beneath Yucca Mountain is estimated to have been at most 120 meters (390 feet) above its present elevation during Quaternary time based on mineralogic data, isotopic data, and discharge-deposit data. An earthquake occurring under these extreme climatic conditions might cause an additional temporary rise in the water table of less than 20 meters (66 feet), still leaving a safety margin of 20 meters (66 feet) or more between the water table and the level of the waste emplacement drifts. The Little Skull Mountain earthquake (magnitude 5.6) raised water levels in monitoring wells at Yucca Mountain less than one meter (DIRS 101276-O'Brien 1993). Water level and fluid pressure in continuously monitored wells rose sharply and then receded to pre-earthquake levels over a period of several hours. The rise of water levels in wells monitored at hourly intervals was on the order of centimeters and indistinguishable after two hours (DIRS 101276-O'Brien 1993).

Szymanski (DIRS 106963-1989) hypothesized that during the last 10,000 to 1 million years, earthquakes and volcanic activity drove hot mineralized groundwater to the surface. This hypothesis goes on to suggest that similar forces could raise the regional water table in the future and inundate the proposed waste emplacement horizon. DOE requested the National Academy of Sciences to conduct an independent evaluation of this issue. The Academy examined the model upon which this theory is based and rejected its most important aspects. The Academy concluded that the evidence cited by Szymanski as proof of groundwater upwelling--exposed vein-like deposits of calcium carbonate and opaline silica--could not reasonably be attributed to that process. Furthermore, the Academy found that the combination of earthquakes and volcanic activity would not raise the water table more than a few tens of meters. Finally, the Academy concluded that the carbonate-opaline veins originated from surface precipitation and surface processes, not from upwelling groundwater.

Dublyansky (DIRS 104875-1998) proposed an alternative interpretation of past groundwater levels at Yucca Mountain. This study examined tiny pockets of water (called "fluid inclusions") trapped in the carbonate-opaline veins at Yucca Mountain. According to Dublyansky, the fluid inclusions indicate that the veins were caused by rising hydrothermal water and not by downward percolation of surface water. A group of project scientists specializing in hydrology, geology, isotope geochemistry, and climatology did not concur with Dublyansky's conclusions (DIRS 100086-Stuckless et al. 1998). DOE has nevertheless agreed to continue funding research on this topic through the University of Nevada-Las Vegas. DOE views this additional research as a supplement to previous efforts. In November 2001, preliminary results were made public that support the earlier conclusions of DOE and the National Academy of Sciences. See Section 3.1.4.2.2 for additional information.

In another opposing view, Davies and Archambeau (DIRS 103180-1997) suggest that an earthquake of moderate magnitude could displace southward the large hydraulic gradient that now exists north of the site. The authors speculate that if this were to occur, the water table at Yucca Mountain could rise 150 meters (490 feet). A severe earthquake, as suggested by the authors, could raise the water table 240 meters (790 feet) and flood the waste emplacement horizon. DOE convened a panel of five recognized groundwater experts to review the issues raised by Davies and Archambeau. The consensus was that a rise in the elevation of the water table due to earthquakes would be neither large nor long-lived (DIRS 100353-CRWMS M&O 1998).

DOE does not believe that the scenarios presented by Szymanski, Dublyansky, and Davies and Archambeau are credible; therefore, they are not reasonably foreseeable. Furthermore, there is no credible evidence to support a rise of the water table to a level that could inundate the waste emplacement horizon. In fact, DOE believes that geologic evidence strongly indicates that water levels have not risen to levels that could affect the performance of the repository. Therefore, DOE did not evaluate the impacts to the long-term performance of the repository from inundation by groundwater because such impacts are not reasonably foreseeable. This approach is consistent with regulations of the Council on Environmental Quality at 40 CFR 1501.1, which directs agencies to focus on significant environmental issues and reduce the accumulation of extraneous background data.

7.5.3.2 (230)

Comment - 42 comments summarized

Commenters said that the repository would contaminate groundwater with radioactive materials and other pollutants that would adversely affect the health of people and wildlife. Some said that DOE did not examine the issue of groundwater contamination in the EIS, or examined it inadequately, or disagreed with the results reported in the Draft EIS. Others said that DOE cannot guarantee that the repository would not contaminate the groundwater and that any contamination is unacceptable. Some feared the repository would contaminate groundwater in a broader area, including Las Vegas, the Colorado River, and other parts of Nevada and California. Others questioned how DOE can reliably predict the release of radioactive materials from the repository over thousands and millions of years considering that the data and models used to make these predictions are not reliable.

Response

Based on the results of analyses reported in Chapter 5 of the EIS, DOE believes that a repository at Yucca Mountain would have negligible short and long-term environmental impacts. DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, which considered faults, earthquakes, volcanism, and fast-flow movement of water through the mountain, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

Sections 3.1.3 and 3.1.4 of the EIS describe the geologic and hydrologic settings of Yucca Mountain and the surrounding region in great detail. Subsections of 8.2 and 8.3 consider the cumulative impacts to groundwater from the repository, the Nevada Test Site, and other activities in the area that could contribute to long-term groundwater pollution. DOE believes that the information in the EIS on the amount and type of contaminants released over time from the repository and from other sources in the region have been adequately described and analyzed in the EIS. Estimated releases to the accessible environment during and after the 10,000-year regulatory period would be limited geographically to the groundwater flow system described in Section 3.1.4.2 of the EIS; contaminants from the repository could not reach the Las Vegas Valley, the Colorado River, or any other parts of Nevada and California.

DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. Section 5.2.4 of the EIS describes how DOE dealt with these uncertainties. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Nuclear Regulatory Commission indicates that absolute proof is not to be had in the ordinary sense of the word (see 10 CFR Part 63), and the Environmental Protection Agency finds that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance (see 40 CFR Part 197).

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to assessing the long-term performance of the repository addresses and compensates for important uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

Meanwhile, DOE recognizes that the acquisition of additional data would further reduce uncertainties. Studies are planned to gather some of this information. Section 2.1.2.3 of the EIS describes the types of tests, experiments, and analyses the Department would conduct during the "performance-confirmation" phase of the program. This program would continue for perhaps as long as 300 years after emplacement ends (through closure of the repository as described in Section 2.1.2). The purpose of the performance-confirmation program is to evaluate the accuracy and adequacy of the information used to demonstrate compliance with performance objectives.

7.5.3.2 (315)
Comment - EIS000002 / 0002
Nevada has a Great Basin, that is, it is a land of interior drainage. Nevada had a violent geologic metamorphosis, millions of years ago, undergoing continual erosion for a long period. It experienced earth movements which have been continual and vigorous to this day in the interiors of its volcanic mountains. As a result, most of the mountain ranges in the Great Basin are bounded by faults on either one side or on both sides of the mountains. During the period of the geologic metamorphosis drainage to the prehistoric seas was disrupted, causing diversion of the streams into the interior basins and setting the basic structure of water to drain into the interior of the faults and crevices of the volcanic mountains. To place canisters or tanks that store nuclear waste into such volcanic

mountains, that could cause these containers to break or leak, is placing the entire interior water supply to the state at great risk for nuclear contamination. The DOE has not addressed this issue sufficiently.

Response
DOE has conducted an extensive site characterization program to evaluate the suitability of Yucca Mountain for a repository. Yucca Mountain is in the Death Valley Regional Groundwater Flow System, which is part of the larger Great Basin physiographic subprovince. This area is characterized by a very dry climate, limited surface water, and very deep aquifers. The region is a closed hydrologic system, which means its surface water and groundwater can leave only by evaporation from the soil and transpiration from plants. The central Death Valley hydrologic subregion is comprised of three groundwater basins that are subdivided into smaller sections. Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin. Some of the water that infiltrates through Yucca Mountain joins groundwater in the Fortymile Canyon section and flows toward the Amargosa River section (see Figure 3-13 of the EIS). Thus, the small fraction of the total water in the basin that might move though a repository would be likely to flow toward the south toward Amargosa Valley, and therefore does not pose any risk of contamination to the entire water supply of the state.

The areas proposed for waste emplacement at Yucca Mountain are located in areas away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release. Additional fault movements or displacements from postemplacement seismic activity would probably be along existing fault planes.

Hydrology models, derived from extensive studies conducted at Yucca Mountain, are based on a fault-fracture flow system. Inception of a few new faults and associated seismic events would have very minor or no effect on the current fault- and fracture-flow pathways, and would therefore be unlikely to alter repository performance. Modeling of long-term performance shows that the combination of natural and engineered barriers at the site would keep releases of radionuclides well below the regulatory limits established at 40 CFR Part 197.

DOE considered volcanic disturbances and conducted extensive assessments. The rocks at Yucca Mountain were formed 11.5 to 14 million years ago by large silicic ash flows that were erupted during a period of intense tectonic activity. The volcanism that produced these ash flows stopped millions of years ago and, based on the geology of similar volcanic systems in the Great Basin, no additional large volume silicic volcanism is likely. Less explosive and much smaller volume basaltic volcanism in the Yucca Mountain region began about 11 million years ago as silicic eruptions waned and continued as recently as 70,000 to 90,000 years ago. Disruption of a repository at Yucca Mountain by volcanoes would be highly unlikely. For more information, see EIS Sections 3.1.3, 3.1.4.2, and 5.4. The chance of a volcanic disruption at or near a repository at Yucca Mountain is one chance in 7,000 during the first 10,000 years after closure (one chance in 70 million annually).

This estimate was recalculated in Section 3.1.3.1 of the Final EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout (one chance in 63 million annually), considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000).

7.5.3.2 (501)
Comment - EIS000125 / 0001
My concern is the perched water and if we had had underground nuclear testing out at the Test Site which has polluted the water out there, and now we have perched water which they have found which has a certain amount of chemicals in it, how are these chemicals in this perched water going to react with the other chemicals that are in these spent fuel rods?

In other words, one radionuclide does not mix with another radionuclide, and what about the isotopes in there? There's a big question here with perched water.

And we're just willing to go out there and just tear everything up we want to tear up to put this spent fuel rod in the ground where we got a possibility of one nuclide mixing with another radionuclide that we have had underground nuclear testing out there and it just is not going to mix.

If we ever had any underground nuclear testing out there, it might be a different story because in that first part, you have different chemicals, but because we have found the chemicals that were in the underground nuclear testing in those perched water -- you're going to put that canister. You don't even know all where the perched water is. You haven't even done that much studying. You have found some. You have admitted to that.

So I think the study of perched water and one radionuclide mixing with the other could cause some major melt down, and then we're just going to be in a big mess.

Response
Section 3.1.4.2.2 of the EIS describes the occurrence of perched water below the area of the proposed repository. Later in the same section, results of water chemistry analysis of the perched water are presented in a table. The constituents identified occur naturally as a result of the water's interaction with the rock through which it passes. This comment appears to express concern over the potential of a nuclear criticality as a result of the mixing of radionuclides outside the disposal containers and as a result of the presence of the perched water. DOE has studied the potential for such a reaction to occur (including effects from the presence of water) as a result of the proposed action. The results of those studies, which characterize the potential for criticality events to range from highly unlikely to not credible, are summarized in Section 5.8 of the EIS.

7.5.3.2 (589)
Comment - EIS000127 / 0006
They found fifteen to thirty fractures per meter in the tunnel that they've drilled. They found crystals that were made by either water going up or water going down and they don't know which, and they found chambers in the mountain, big ones that they tried to fill up with gravel before their own scientists got to look at it.

Response
As part of its site characterization activities, DOE built the Exploratory Studies Facility for scientific and engineering studies, testing, and experiments (see Section 1.4.3.1 of the EIS). The objective of these subsurface investigations is to obtain an understanding of conditions in the potential repository horizon and in the overlying rock units. The Exploratory Studies Facility intersects a zone that contains a relatively high concentration of fractures (DIRS 101367-Albin et al. 1997). This zone consists of more than five fractures per linear meter of tunnel. Most of this intense fracturing occurred adjacent to faults. The Main Drift in the area of the fracture zone is parallel to the Ghost Dance Fault approximately 100 meters (330 feet) to the east. In general, the intense zone of fracturing appears to occur only in the middle nonlithophysal zone of the Paintbrush Group (DIRS 101367-Albin et al. 1997). Fracture frequency is lower in other parts of the Main Drift (DIRS 101367-Albin et al. 1997).

Because borehole samples drilled before the excavation of the Exploratory Studies Facility contained mineral crystals, DOE anticipated the presence of fractures in the subsurface and planned to study their characteristics. As the comment indicates, scientific activities in the Exploratory Studies Facility mapped, sampled, and analyzed additional mineral crystals. The information obtained by scientists working on the Yucca Mountain Project agrees with the results of earlier studies reviewed by the National Academy of Sciences that concluded that the downward percolation of groundwater caused the formations of the crystals. Section 3.1.4.2.2 of the EIS discusses this issue and alternative interpretations.

During excavation of the Exploratory Studies Facility, DOE inspected conditions to determine if the Bow Ridge fault zone had been intersected and found a "chamber" or void (DIRS 152214-Elkins 1995). At the time of the inspection, there was an opening at the top of the cutter head of the tunnel-boring machine that was 2 to 3 meters (7 to 10 feet) wider than the tunnel. The opening extended about 6 meters (20 feet) above the shield of the tunnel-boring machine, tapering to less than 0.5 meter (1.6 feet) near the top of the opening. The opening was at most about 2 to 3 meters thick (normal to the tunnel). The upper 3 to 4 meters (10 to 13 feet) of the opening was smooth, indicating that it probably existed before the excavation. It was photographed, the material was sampled, and the opening was stabilized before excavations proceeded. Analyses indicated that fibercreting the void face and filling the void with lean cement would not interfere with planned test activities at the Bow Ridge fault zone.

7.5.3.2 (725)
Comment - EIS000210 / 0003
Ground water migration in the area is also well documented and should add to the scientific basis for rejecting this as the final selected site as a high level nuclear repository. Please take some time to review the literature to evaluate the impacts of 'what if' scenarios if these waste chambers become flooded and radionuclides are leached into the groundwater. What have past radioecology studies at Nevada Test Site, Chernobyl, Rocky Flats, Project Rio Blanco, Hanford and other hot sites where tritium, etc. have been known to migrate off site taught us? Cannot correlations be drawn for Yucca and its surrounds? Should not the EIS ask these extremely difficult, worst case questions? That way everyone goes into this Waste Priesthood, a clearly defined group of elite individuals who will need to be trained and cultivated to watch over and safeguard this waste for the material's life some tens of thousands of years, with a full understanding and at least a plan for eventual catastrophic seismic failure.

Response
The possibility of groundwater rising sufficiently in the future to inundate the waste packages is remote. There are no credible mechanisms that can account for such a rise. Szymanski (DIRS 106963-1989) proposed that during the last 10,000 to 1,000,000 years, earthquakes and volcanic activities drove hot mineralized groundwater to the surface, and deposited calcite and opal at Yucca Mountain. This hypothesis goes on to suggest that similar forces could raise the regional groundwater in the future and inundate the repository.

To investigate this hypothesis further, DOE requested the National Academy of Sciences to conduct an independent evaluation. The Academy concluded in its 1992 report (DIRS 105162-National Research Council 1992) that no known mechanism could cause a future inundation of the repository horizon. The geologic evidence indicates that groundwater never reached the repository horizon; in fact, the largest rise seems to have been about 120 meters (390 feet) during the last several million or more years. Based on simulations of earthquake effects, the predicted water table rise could be about 20 meters (66 feet) at most. The 1992 Little Skull Mountain earthquake raised water levels in some monitoring wells by a maximum of less than 1 meter.

Dublyansky (DIRS 104875-1998) proposed another line of data in support of the warm water upwelling hypothesis. That study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. It concluded that some crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of independent experts, including scientists from the U.S. Geological Survey, did not concur with Dublyansky's conclusions. DOE disagrees with the central conclusions in this report, but has supported continuing research by the University of Nevada, Las Vegas. EIS Section 3.1.4.2.2 contains more information on groundwater at Yucca Mountain.

The comment refers to several other places that might offer insights to processes at Yucca Mountain. DOE recognizes the value of such comparisons, but realizes the need for care in the selection of an appropriate site for comparison to process of interest at Yucca Mountain. An ideal comparison site to long-term radionuclide transport at Yucca Mountain would have to satisfy the following conditions: (1) a known source term, (2) a similar set of radionuclides, (3) well characterized site data, (4) similar geologic conditions, (5) observable long-term conditions, (6) identifiable boundaries of the system, and (7) a clear-cut process that can be separated from other processes.

An example of a comparison site mentioned by the comment is the April 1986 accident at the Chernobyl nuclear power plant. After studying this accident, DOE determined that the conditions at Chernobyl and Yucca Mountain are different in several major aspects, such as climate, geologic and tectonic setting, and depth to the water table. The Chernobyl catastrophe was an above-ground explosion accompanied by an atmospheric release of radionuclides, with subsequent contamination of the land surface. Radionuclides that descended from the atmosphere to the land were distributed through surface-water reservoirs, and then entered the unsaturated zone and percolated down through zones of preferential flow toward the water table. In contrast, atmospheric transport at Yucca Mountain would not be a factor, and surface-water transport of radionuclides would be negligible. Furthermore, the suite of radionuclides at Yucca Mountain would be somewhat different from the radionuclides at Chernobyl.

Background conditions and expected modes of contamination for Chernobyl and Yucca Mountain are not directly analogous. What DOE learned from reviewing the more than 13 years of investigations of infiltration and contaminant transport at Chernobyl can provide insight to some of the flow and transport processes at Yucca Mountain. The most important conclusions of this study are as follows:

1. Spatial and temporal variations of infiltration rates and fast preferential flow in the near-surface zone depend on topography. Near-surface fast infiltration and migration of radionuclides in the unsaturated zone occur in surface depressions. Despite the low level of contamination detected in groundwater, the appearance of Chernobyl radionuclides confirms the presence of localized, preferential, radionuclide transport though the unsaturated zone.

2. Rapid groundwater contamination around Chernobyl might not be associated directly with the near-surface zones of preferential flow.

3. Section 13 of the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) contains a more complete discussion of DOE's natural analog study.

7.5.3.2 (870)
Comment - EIS000252 / 0004
Sometimes I refer to the Yucca Mountain facility as just the parking lot for this high level waste is that the mountain has been -- in more recent research the mountain is not going to be the primary thing that is going to contain the waste. It is going to be the canister and the containers.

Response
As described in Section 2.1 of the EIS, DOE is relying on both the inherent geologic features of the mountain and manmade barriers to ensure the long-term isolation of the spent nuclear fuel and high-level radioactive waste from the human environment. The packaging or container holding the materials when they are emplaced in the repository is a major component of the engineered barriers.

7.5.3.2 (914)
Comment - EIS000089 / 0003
We get a lot of rain one year and then a couple years we don't get no rain at all, so they average things out. They come up with these working models that don't work.

We know that for sure right now because, you know, back in the '90s when we were setting off the bombs in the ground, we said, "Hey, that's going to contaminate the groundwater."

They said, "Oh, no. It's not going to contaminate the groundwater. It's going to be contained." These bombs are going off, they create these lasts pops underneath and that bomb is so hot, it just melts everything around it. There's no problems here.

Even if it does get into the groundwater, that groundwater will never move.
Now they're talking about plumes underwater, underground. I was so disgusted the other way. I know this DOE is putting this information out. You guys are liable to us. You're going to have to live with yourselves.

So what are we going to do? We're sitting out here. First they said, "Don't worry about it, folks. It's never going to move, the groundwater even if it does get contaminated."

"Well, it's moved a mile away from the site. We've detected the radiation in the groundwater. May be our models weren't right, so we're figuring 10,000 years before it reaches Death Valley."

Response
Many of the studies conducted at Yucca Mountain are designed to help DOE make reasonable projections of how and when contaminants in the groundwater might travel from the repository. The explanations in the EIS present the consensus understanding of experts working for DOE, its contractors, other government agencies, academia, and the public sector. The projections consider not only average and worst-case environmental parameters (such as precipitation and infiltration) from measured values in current and historical records, but also geologic-scale evidence to determine what occurred in the past and, therefore, what might occur in the future.

As suggested by the commenter, the amount of water moving through the mountain is one of the key parameters incorporated in the projection of contaminant movement. As described in Sections 5.2.4.1 and I.2.2 of the EIS, the performance assessment includes a large range of water fluxes reflecting wide rainfall variations that could occur over thousands and hundreds of thousands of years, and assumes that the current climate is the driest it will ever be at Yucca Mountain.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials. Section 5.6 of the EIS contains additional information.

7.5.3.2 (949)
Comment - EIS000259 / 0001
Inyo County is very concerned about the long-term threat the repository poses to regional groundwater supplies and to communities east of the Owens Valley. Hydrologic studies conducted by Inyo, Nye and Esmeralda Counties point to the existence of a continuous aquifer running from beneath Yucca Mountain southwards to Tecopa, Shoshone and Death Valley Junction. These studies also support the contention that water flowing beneath Yucca Mountain flows southeast to become surface water flowing into Death Valley. Some of this water is used in Death Valley for commercial and domestic purposes, and of course supports natural habitat under Federal protection.

The two studies I'm referring to are a 1996 publication titled "An Evaluation of the Hydrology at Yucca Mountain: The Lower Carbonate Aquifer and Amargosa River" and the 1998 "Death Valley Springs Geochemical Investigation." These studies were conducted with Federal funding in accordance with USGS quality assurance and quality control measures, and will be submitted to DOE in conjunction with our written comments in January.

Nowhere in the Environmental Impact Statement does DOE address our findings, either to acknowledge or deny the implications of these studies with regard to potential pathways for contaminants to reach human populations or a National Park. These studies have been available to DOE for some time and are absent from the 50,000 pages of technical background material which went into development of the EIS.

This is a critical oversight on the part of DOE, which needs to be corrected by serious consideration of the scientific work sponsored by the County and the placement of our findings in the proper context.

Response
DOE acknowledges in the EIS that the groundwater flowpath from Yucca Mountain includes the locations identified by the commenter, with the exception of the Owens Valley area. Section 3.1.4.2.1 describes groundwater beneath Yucca Mountain as flowing to Jackass Flats, the Amargosa Desert, and then south to the primary point of discharge at Franklin Lake Playa in Alkali Flat, which is southeast of Death Valley Junction. The EIS states that some groundwater reaching this far might bypass the playa and continue into the Death Valley basin, which would require flow through the Tecopa and Shoshone areas. The EIS recognizes that a small amount of the groundwater beneath the Amargosa Desert might flow through the southeastern end of the Funeral Mountains toward springs in the Furnace Creek Wash area of Death Valley.

Chapter 5 of the EIS does not specifically address risks to people and natural resources in Tecopa, Shoshone, or Death Valley National Park as a result of groundwater use and consumption. However, the evaluation in Chapter 5 clearly shows that risks would decrease with increased distance from the repository. Accordingly, impacts to these other areas, because they are farther away along the groundwater flowpath, would be less than those for the farthest distance evaluated in the EIS. Section 5.9 addresses impacts to biological resources as a result of long-term repository performance. As indicated in that section, DOE does not quantify impacts to biological resources as a result of exposures to contaminated groundwater, but relates them to the minimal impacts expected for humans through the use and consumption of the groundwater.

As described in Section 3.1.4 of the EIS, the Death Valley regional groundwater flow system is a terminal hydrologic basin. That is, there is no natural pathway for groundwater or surface water to leave the basin other than by evaporation or transpiration through plants; Death Valley is the lowest part of the basin. With this in mind, impacts to groundwater east of Owens Valley, but outside the Death Valley flow system, would not occur. For areas within the Death Valley flow system, but west of Death Valley, any contaminants reaching Death Valley over thousands of years would have to flow up the hydrologic gradient on the west side of Death Valley to reach areas east of Owens Valley which would not occur.

DOE received the two reports identified in the comment. It did not reference them in the EIS (similar to many other reference sources), because the conclusions they present are not contradictory or inconsistent with the information in the EIS. For example, the primary conclusion of the "Geochemistry" report is as follows: "The water can come from recharge in 1) the area of NTS [Nevada Test Site] and Yucca Mountain; or 2) the Amargosa Basin fill deposits, or 3) the area to the east that includes the Ash Meadows springs, or some combination of all three" (DIRS 147808-King and Bredehoeft 1999). The EIS identifies the apparent link of groundwater from beneath Amargosa Desert to the Furnace Creek springs and suggests that the link could involve groundwater from beneath Yucca Mountain by identifying it in the flowpath. The earlier "Lower Carbonate Aquifer" report concludes that (1) groundwater movement beneath Yucca Mountain is upward out of the carbonates into the tuff; (2) if contaminants reach the carbonates, travel times could be relatively short; (3) discharges to springs on the east side of Death Valley appear to be linked to the carbonates; (4) Esmeralda County is not in the groundwater flow path from Yucca Mountain; and (5) there are geohydrologic data gaps for the carbonate aquifer (DIRS 147808-Bredehoeft, King, and Tangborn 1996). These conclusions are consistent with data and analyses in the EIS.

7.5.3.2 (1146)
Comment - EIS000087 / 0003
Furthermore, you heard about volcanism. Well, that translates to volcanic activity nearby. Well, the water comes out of my wells is 70 degrees. That's warm for subterranean water.

It says there's current volcanic activity, and my well is not the only well in the valley. In fact, it's very typical of the temperature of the water comes out of the ground.

And right next to Yucca Mountain, which no one seems to talk about, where the cinder cone mining is, well, the cinder cone where they're mining, where they're taking cinders out a recent volcanic upheaval of lava which formed the cinder cone.

You can look at Yucca Mountain and you look slightly to the right or the east and there's very volcano sitting there.

It's not something that the average geologist should be able to miss.

Response
The volcanic history of Yucca Mountain and surrounding areas is described in Section 3.1.3 of the EIS. This section describes the location and nature of volcanic eruptions in the Yucca Mountain area (the most recent of which occurred about between 70,000 and 90,000 years ago), as well as the possibility of their recurrence (unlikely). The EIS makes specific mention of the cinder cones that can be seen in the area. In describing current land use at Yucca Mountain, Section 3.1.1.2 mentions the mining of volcanic cinders (at the cone just north of U.S. 95).

Section 5.7.2 of the EIS provides further discussion on evaluations that have been performed on the probability of volcanic activity recurring in the area of Yucca Mountain. This section discusses the affect that such an unlikely event might have were it to occur, including the intrusion of liquid magma or hot gases into the repository.

With regard to the temperature of groundwater, groundwater temperature tends to approach the mean annual temperature of the air. In the Amargosa Desert – Las Vegas area, the mean annual air temperature is about 18º to 19º C (64º to 66º F) (DIRS 151945-CRWMS M&O 2000). A slight elevation in water temperature above the annual average air temperature is probably due to contributions from deeper aquifers where the water is warmer. Some researchers (DIRS 103415-Dudley and Larson 1976) concluded that flow in the lower carbonate aquifer intercepts crustal heat flow and transports it laterally toward discharge areas. As an alternative, it might be the result of deeper warm water rising along the fault line.

7.5.3.2 (1177)
Comment - EIS000111 / 0001
While, when I was out in Ash Meadows, I was reading some literature from the Park Service there and apparently -- oh, quite sometime ago, I can't remember what. I couldn't find the article.

Anyway, some divers went down in Devil's Hole or one of those springs there and disappeared.

Well, a few months later, they found one of the diver's tanks in it -- what is it Sea of Cortez or the Gulf of California, you know, down in Mexico, and then I'm not sure what government agency did it, but they added some dye to the spring, and within a short time -- and I can't remember whether it was days or a couple weeks -- it showed up in -- again in the Sea of Cortez or whatever you call that Gulf of California.

Well, this brings an international aspect into contamination of groundwater, and I think this very definitely needs to be addressed, and with our research techniques in looking for oil and so forth, ground penetrating radar and whatever, I'm sure that this deep aquifer, wherever it is, or river or whatever it is, can be found and located and tested.

The surface flow definitely goes down a few hundred feet, goes along the Amargosa River and then on into Death Valley, but the deeper flow apparently goes into Mexico.

Response
There is no connection between Devils Hole or Ash Meadows and the Sea of Cortez. Yucca Mountain is in the Death Valley hydrologic basin, which is part of the larger Great Basin physiographic subprovince. This area is characterized by a very dry climate, limited surface water, and very deep aquifers. The Death Valley basin is a closed hydrologic basin, which means that its surface water and groundwater can leave only by evaporation from the soil and transpiration from plants.

The general path of the groundwater that infiltrates through Yucca Mountain is southward and includes flow in Amargosa Desert near Ash Meadows and Devils Hole. In this area there is a marked decline of about 64 meters (210 feet) in the water table elevation between Ash Meadows and the low axis (Carson Slough) of the Amargosa Desert area to the west and south. This elevation decline indicates that the groundwater flow is from Ash Meadows toward the Amargosa Desert, not the other way around. Therefore, potential contamination from Yucca Mountain could not discharge to the surface at Ash Meadows or Devils Hole. Sections 3.14.2.1 and 5.3 contain more information.

7.5.3.2 (1477)
Comment - EIS001521 / 0011
Page S-41, fifth paragraph--The term "perennial yield" is confusing. Perennial usually refers to surface water (stream) conditions and indicates that water is flowing along the stream course on a continuing basis, but it has no connotation in terms of base-flow quantities and/or volumetric measurements. Ground-water hydrologists usually use the term "safe yield" (which no one really likes or has adequately defined) or the term "optimal yield" (defined by a set of socio-economic objectives associated with ultimate water use). In either case, the concern is to prevent overdraft of an aquifer (water being discharged from an aquifer is greater than recharge water coming into it), but to use a term that supposedly relates to overdraft concerns, and that heretofore has not been used in the hydrological sciences causes confusion (an element of the DEIS that should be eradicated, or at least, limited).

Response
The term "perennial yield," which is equivalent to the term "safe yield," is commonly used by the Nevada State Engineer's Office in relation to water appropriations. The definition used in the EIS (Summary Section S.4.1.4 and in Section 3.1.4.2.1) was established by Walker and Eakin (DIRS 103022-1963) as "the maximum amount of water that can be withdrawn from the groundwater system for an indefinite period of time without causing a permanent depletion of the stored water or causing a deterioration of the water." This definition is also used by the Nevada State Engineer's Office. The term "safe yield" has been added to the EIS in parentheses where appropriate.

7.5.3.2 (1482)
Comment - EIS001521 / 0021
Page 3-22, Figure 3-7--There are many more than the three or four "major" faults shown on this figure (see page 3-23, Figure 3-8, and page 3-27, Figure 3-10), and as such, the figure presents a very unrealistic presentation of the faulting in the repository area.

Response
This figure has been updated and includes additional faults in the repository block area.

7.5.3.2 (1483)
Comment - EIS001521 / 0022
Page 3-23, Figure 3-8--The geology and faulting presented on this cross-section does not correlate well with the B-B' trace on page 3-22, Figure 3-7. The cross-section should be simplified to accurately represent the trace as shown on the generalized bedrock geology map.

Response
DOE has updated this figure in Section 3.1.3 of the Final EIS. The faults shown on the cross-section now correspond to the faults shown on the updated geologic map.

7.5.3.2 (1491)
Comment - EIS001521 / 0020
Page 3-17, Figure 3-5--(Legend) No ages for the "Caldera volcanic center" and "Other bedrock" units are given, while the others show approximate ranges. Consistency is needed. Also, Qby, Qbo, Typ, and Tyb are not defined here or in the text. Do these units relate to page 3-19, Table 3-6, or page 3-20, Table 3-7?

Response
DOE has added a range of ages for the caldera and bedrock designations to the legend of Figure 3-5 of the EIS, and an explanation to clarify rock designations to the footnote in the figure (such as Qby, Typ, and Tyb). The figure shows the locations of calderas and generalized age groupings of volcanic rocks and does not correspond directly to all the units listed in Tables 3-6 and 3-7 in Section 3.1.3.1.

7.5.3.2 (1493)
Comment - EIS001521 / 0032
Page 3-36, 3.1.4.2.1 Regional Ground Water, first paragraph--Concerning the "confining unit" statement, see Summary, comment number 7 in this review.

Response
DOE agrees that, technically, a confining unit does not allow movement of considerable quantities of water between aquifers. In some areas of the Death Valley region, the confining units do allow considerable water movement and should more properly be called *aquitards*. However, these units are sufficiently confining to support artesian conditions over much of their distribution in the regional basin.

7.5.3.2 (1494)
Comment - EIS001521 / 0033
Page 3-37, second paragraph--(Basins) In discussing regional geographic features, a reference to page 3-38, Figure 3-13 should be made (or to another figure that shows the entire Death Valley region). Also, recharge and discharge points would be much easier to visualize with a figure. According to page 3-38, Figure 3-13, ground-water flow is primarily to the south; the only western flow-direction arrow shown is questioned.

Response
DOE agrees that a reference to a figure would be helpful. This section of the Final EIS now includes a reference to a new figure that shows the entire Death Valley regional flow system. The figure that was Figure 3-13 in the Draft EIS continues to be referenced later in the discussion. In addition, in Figure 3-13 the Spector Range section and the Indian Springs Valley section show a groundwater flow to the west, so not just the Funeral Mountain section has a western flow-direction arrow.

7.5.3.2 (1495)
<u>Comment</u> - EIS001521 / 0034
Page 3-37, third paragraph--All of the comments listed in the Summary items numbered 8, 9, and 10 in this review are pertinent to this paragraph and page 3-38, Figure 3-13. Also, were ground-water levels measured in wells that were completed in the same aquifer? If not, this would make the potentiometric-surface map useless (a figure showing this surface would also help). Statement about "other data" should be referenced. Mention in the discussion that flow in the aquifer(s) below Yucca Mountain is addressing primarily the water-table aquifer. Likewise, discharge areas relevant to the aquifer(s) underlying Yucca Mountain are also in reference to the water-table aquifer, or are they? Clarification is needed.

<u>Response</u>
The responses to the referenced comments on the Summary (numbered 8, 9, and 10) identified changes to the Final EIS that have been applied to subsections of Chapter 3.

With respect to the comment about the comparability of wells completed in different aquifers, the *Yucca Mountain Site Description*, provides interpretations of report data to define regional potentiometric levels and hydraulic gradients (DIRS 151945-CRWMS M&O 2000). Among these interpretations are the following:

1. Although the consolidated rock commonly has very low permeability, and very low rates of groundwater flow, the entire groundwater system, valley-fill and bedrock, should be treated as one integral system.

2. Though vertical gradients exist between the valley-fill aquifers and consolidated bedrock aquifers, on a regional scale, the potentiometric levels are similar enough that all water level data, regardless of well construction, can be used to define regional potentiometric levels.

Regarding the validity of the water-level monitoring program and resulting potentiometric maps, the commenter is referred to D'Agnese et al. (DIRS 100131-1997) with respect to the Death Valley region, and to Luckey et al. (DIRS 100465-1996) with respect to the Yucca Mountain vicinity. A figure, showing the potentiometric surface of the Death Valley basin from D'Agnese et al. (DIRS 100131-1997), has been added to the EIS in Section 3.1.4.1.2.

The statement concerning "other data" is intended to be a simple concession that more than "water levels in wells" has gone into the generation of regional potentiometric surface maps. More detail on the other types of information and interpretations used can be found in the Site Description (DIRS 151945-CRWMS M&O 2000).

The groundwater flow path described in Section 3.1.4.2.2 is from the volcanic aquifers beneath Yucca Mountain to the alluvial aquifers beneath Amargosa Desert. These are the aquifers in which the water table occurs in these areas, but the DOE is hesitant to introduce additional aquifer terminology to this already complicated discussion. DOE believes that the current description presents an adequate picture of groundwater flow to the average reader. The referenced documents provide additional information.

7.5.3.2 (1496)
<u>Comment</u> - EIS001521 / 0036
Page 3-37, fifth paragraph--Pahute Mesa-Oasis Valley ground-water sub-basin includes "all" of Gold Flat and Oasis Valley; southern part of Cactus Flat; and southern part of Kawich Valley (designated a ground-water section, so it must be important). See page 3-38, Figure 3-13, for name locations.

<u>Response</u>
DOE has modified the text to better describe the area included in the Pahute Mesa-Oasis Valley groundwater basin.

7.5.3.2 (1497)
<u>Comment</u> - EIS001521 / 0035
Page 3-37, fourth paragraph--Is outflow from the Ash Meadows ground-water sub-basin, in part, to a lower portion of the Alkali Flat-Furnace Creek Ranch ground-water sub-basin? Is the latter basin composed of upper and lower aquifer units, or is this merely referring to an entry point and the incoming ground water becomes homogenized volumetrically in the Alkali Flats-Furnace Creek Ranch water-table aquifer? Again, a potentiometric-surface map would greatly facilitate the visualization of these concepts. Also, Ash Meadows is the primary discharge point for

which sub-basin? Are the springs at Ash Meadows a discharge point for the water-table aquifer (for which the sub-basin designations have been defined), or for a deeper confined aquifer (the lower carbonate aquifer on page 3-45, Figure 3-15)? A reference is needed for the statement "...springs occur in a line along a major fault."

Response
As described in the Basins discussion in Section 3.1.4.2.1, groundwater in the Ash Meadows basin that does not discharge at the springs travels to the alluvial aquifers at the south end of the Amargosa Desert (which is in the Alkali Flat-Furnace Creek basin), as suggested by most investigators (DIRS 101167-Winograd and Thordarson 1975; DIRS 101125-Claassen 1985; DIRS 103010-Kilroy 1991; DIRS 100131-D'Agnese et al. 1997; DIRS 148866-Laczniak et al. 1999). In addition, most investigators suggest that the alluvial fill of the Alkali Flat-Furnace Creek groundwater basin is underlain by the lower carbonate aquifer. However, deep drilling has not verified this, and the lateral continuity and hydrologic properties of the lower carbonate aquifer beneath the Alkali Flat-Furnace Creek groundwater basin are unknown. In the alluvial aquifers of the Amargosa Desert, mixing probably occurs as the flow continues toward the south. The Final EIS now contains a regional potentiometric surface map.

Ash Meadows is the primary discharge point for the Ash Meadows Groundwater Basin (as shown in Figure 3-13). The Final EIS applies "basin" and "section" terminology uniformly. As indicated in the last paragraph of the introduction to Section 3.1.4.2.1, at least part of the water discharged at the springs in the Ash Meadows area is from the carbonate aquifer.

The reference for the sentence containing "…springs occur in a line along a major fault…," as well as the next sentence, is D'Agnese et al. (DIRS 100131-1997) as well as the Site Description (DIRS 151945-CRWMS M&O 2000).

7.5.3.2 (1498)
Comment - EIS001521 / 0037
Page 3-38, Figure 3-13--The Amargosa Desert is not shown on this figure. Again, is it Alkali Flats-Furnace Creek ground-water sub-basin or Alkali Flats-Furnace Creek "Ranch" ground-water sub-basin?

Response
DOE has added "Amargosa Desert" to the groundwater basin figure in Section 3.1.4.2.1. The correct name is the "Alkali Flat -- Furnace Creek groundwater basin"; "Ranch" has been deleted from the name.

7.5.3.2 (1772)
Comment - EIS000572 / 0004
The ground water, there are no water rights left in Nevada. Las Vegas, everything, they are fighting over the water rights for the Truckee River. Some don't have irrigation or anything else.

If we lose more water because of radiation leaks, then what are we going to do? I mean, if we have no water because we have messed up, we have put radioactivity into it, just because we decided that there is no other suitable site for it.

Response
DOE recognizes the importance of water to the inhabitation and development of land in southern Nevada. The EIS points out that groundwater availability is a concern in many of the areas that the repository or associated transportation actions could affect. Chapter 3 notes (see Table 3-11) that current water appropriations for the Amargosa Desert are higher than some estimates of perennial yield for that area (though actual withdrawals are much less).

In discussing potential Nevada routes for transporting spent nuclear fuel and high-level radioactive waste to the proposed repository, the EIS identifies hydrographic areas crossed by routes that are "Designated Groundwater Basins" (see Tables 3-39, 3-40, and 3-57). The State of Nevada places this designation on hydrographic areas where permitted water rights approach or exceed the estimated perennial yield, and the water resources are being depleted or require additional administration, including State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Tables 3-39 and 3-57 indicate that the Las Vegas and Amargosa Desert areas are Designated Groundwater Basins, and that the Jackass Flats area (hydrographic area 227A), from which DOE would withdraw water for the proposed repository, is not. However, Section 4.1.3.3 recognizes that groundwater withdrawn at Jackass Flats would to some extent reduce the amount of underflow that would reach downgradient areas. In addition, it indicates that the Amargosa Desert would be the first area to experience such an impact, and that the amount of water required by the repository would be very small in comparison to the amount already being withdrawn in that area. In summary, water is a critical factor in the region, but the amount of water needed to support the Proposed Action would be minor.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

7.5.3.2 (2228)
Comment - EIS000622 / 0012
There's also a concern about what water will be used in that area. The water in that area that is being discussed for use in making cement and that kind of thing, spraying down the grounds, is already potentially contaminated from testing. Testing took place above, below and actually within the water table at the Nevada Nuclear Test Site.

Response
Section 3.1.4.2.2 of the EIS addresses groundwater quality. As part of DOE's effort to characterize Yucca Mountain, DOE has monitored water quality in wells and springs throughout the area. There is no indication that DOE activities at the Nevada Test Site have contaminated the groundwater beneath Yucca Mountain or the water in wells J-12 and J-13, which is used for site characterization activities at Yucca Mountain. The nuclear tests referred to in this comment occurred 30 to 40 kilometers (19 to 25 miles) northeast of the Yucca Mountain site. There is evidence from monitoring at the Nevada Test Site that plutonium has migrated about 1.3 kilometers (0.8 mile) from one underground test (DIRS 101811-DOE 1996). For analytical purposes, Section 8.3.2.1.1 of the EIS assumed that radioactivity from weapons testing on the Nevada Test Site would eventually be transported by groundwater to the same sites analyzed in the EIS for releases from the repository. The cumulative dose from the repository and the Nevada Test Site 18 kilometers (11 miles) south of the repository after 10,000 years is estimated in the EIS to be 0.42 millirem per year [0.22 millirem from the repository (the mean dose) and 0.2 millirem from weapons testing].

7.5.3.2 (2267)
Comment - EIS000540 / 0001
DOE studies show the surface water infiltration and the rate of ground water contamination will take place in the Yucca Mountain area much more rapidly than previously thought. As a result of those studies, we believe that there is a potential for radionuclide exposure to residents living nearby in the Amargosa Valley.
Nevada's largest dairy which serves the Los Angeles commercial market is located in that valley. And I believe the Draft Environmental Impact Statement fails to address this issue.

Response
Ongoing studies suggest that water travels through the unsaturated zone at highly variable rates. Groundwater travel times for contaminants from the repository that enter the accessible environment (specified in 40 CFR Part 197) are on the order of thousands to tens of thousands of years. The natural discharge of groundwater from beneath Yucca Mountain probably occurs far to the south at Franklin Lake Playa more than 60 kilometers (37 miles) away and travel times would be even longer. Modeling of long-term performance of the repository shows that the combination of natural and engineered barriers at the site would keep the radionuclides well below regulatory limits established at 40 CFR Part 197.

In evaluating the potential human health impacts of the repository, DOE considered all exposure pathways, including agricultural and animal products such as milk, for residents of Amargosa Valley. These pathways are included in the dose factors described in Section G.2.4.1 for operations and Section I.4.4.6 for long-term performance. From these analyses, DOE concluded that no latent cancer fatalities would occur in the surrounding populations from exposure to ionizing radiation from the Yucca Mountain Repository during operations and during the 10,000-year postclosure period. The potential exposure to ionizing radiation for anyone outside Amargosa Valley would be negligible.

7.5.3.2 (2301)
Comment - EIS000568 / 0003
I particularly am in disagreement with the ground water situation. First of all, it is really vague in the EIS. You try to look it up, you can't even find it. It's in other portions of the text. It's really scattered. But basically what I understood from it is your solution to the pollution is dilution. That's so bogus.

So I would like to see that if nothing else corrected.

Response
Groundwater is discussed in many separate sections of the EIS because DOE followed the standard format recommended for EISs by the Council on Environmental Quality (40 CFR Part 1502.10). Each of these groundwater sections is listed in the Table of Contents to the EIS.

As described in the EIS, contaminants that may eventually escape from the repository would most likely move in thin vertical plumes through flow tubes beneath the repository. This flow model would tend to reduce the amount of contaminant dispersion and dilution compared to a model in which these contaminants would mix on a large scale with groundwater flow in the saturated zone. Dilution of contaminants is a process that would occur in the natural environment at Yucca Mountain. DOE has incorporated this process into the models of the long-term performance of the repository based on the best understanding of the site.

7.5.3.2 (2386)
Comment - EIS000111 / 0002
We have access throughout through springs in the Amargosa area.

So whether it was USGS or whoever who did the testing felt the water was so deep in the ground that it wouldn't be economical to pump, and there's plenty of other groundwater, so they didn't pursue it any further, but I think this needs to be addressed, because it would be a great resource for southern Nevada, but also it's something that apparently in some areas is close enough to the surface to be seen, as the springs in Ash Meadows are, and so it would be contaminated, and the general groundwater flow seems to come down that way.

Response
DOE assumes that this comment refers to discussions in Chapter 5 of the EIS on the selection of locations to be evaluated for impacts related to the long-term performance of the proposed repository. In describing impacts from the slow release of contaminants over thousands of years from the repository, Chapter 5 explains that because groundwater would be the primary transport mechanism, the locations of highest impact would be along the groundwater flowpath downgradient of the repository site. It also explains that the highest possible exposure scenario would be to individuals living along the flowpath who would be using and consuming the groundwater and consuming their own crops and livestock watered from the same source.

Section 5.3 of the EIS indicates that the place closest to the repository site where people currently live is about 20 kilometers (12 miles) to the south in the direction of groundwater flow (southeast to south) where groundwater is about 100 meters (330 feet) below the ground surface. (The Draft EIS inappropriately linked the depth to groundwater to the 5-kilometer distance. DOE has corrected this in the Final EIS.) Closer to the repository, the depth increases to more than 200 meters (660 feet), while it decreases farther south (into the Amargosa Desert). As stated in the EIS, groundwater depths much more than 100 meters would impose economic constraints on agricultural uses of the land. Therefore, the hypothetical exposed individuals might never be closer than 18 kilometers (11 miles) from the site, and there are no people in the area now.

The comment is correct that there is groundwater available and that it is currently used in areas such as Amargosa Desert, but the depths to groundwater in these areas are shallower than they are closer to the proposed repository site. The comment is also correct that there are springs in the area, but none has been identified on the specific groundwater flowpath between Yucca Mountain and Alkali Flat. The many springs of the Ash Meadows area are close to this flowpath, but they contribute water to the flow rather than receive water from it (see Section 3.1.4.2.1 of the EIS).

7.5.3.2 (2498)
Comment - EIS001912 / 0044
Groundwater section needs a map showing different aquifer systems in the region of influence. Groundwater section needs a figure showing all springs in the area and discussion of the relationship of the springs to the various aquifers, if any. There is also a need to describe baseline information on water chemistry in the region of influence.

Response
DOE agrees that an additional figure would help readers understand the relationship of the different aquifer systems in the region and has, therefore, has added a figure to Section 3.1.4 of the EIS showing a generalized hydrogeologic cross-section from Yucca Mountain to the northern portion of the Amargosa Desert. The figure is a simplified representation of groundwater levels, aquifers, and confining units in this area.

DOE believes that Section 3.1.4 of the EIS adequately describes the general location of major springs in the region of influence and that a figure showing these locations is not required. The area of primary interest is the pathway that groundwater travels from beneath Yucca Mountain. As described in Section 3.1.4.2.1, this pathway is to Jackass Flats, to Amargosa Desert, and then to Death Valley. Section 3.1.4.2.2 describes the aquifers involved in this flowpath. The primary point of discharge along this path is Franklin Lake Playa in Alkali Flat, although some of the flow from the Amargosa Desert might travel to the Furnace Creek area of Death Valley. Figures 3-15 and 3-20 both show Alkali Flat and Furnace Creek. There are no other major springs or seeps along the pathway from Yucca Mountain.

A fraction of the groundwater might flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains toward spring-discharge points in the Furnace Creek area of Death Valley. Several large springs (Texas, Travertine, and Nevares) in the Furnace Creek Wash area of Death Valley discharge about 4 million cubic meters (3,250 acre-feet) per year near Furnace Creek Ranch on the east side of Death Valley.

The EIS mentions other well-known springs in the region, even though they are not in the groundwater pathway from Yucca Mountain. The best known are near Beatty, and in Ash Meadows. Section 3.1.4.2.1 of the EIS discusses the springs in Ash Meadows and Figures 3-15 and 3-20 show the location of Ash Meadows. In addition, Section 3.1.4.2.2 identifies Saturated Zone Groundwater Quality in two of the sampling points as springs in the Ash Meadows area. These springs are listed in Table 3-19 and shown in Figure 3-20.

The EIS contains several discussions of groundwater chemistry and quality. Section 3.1.4.2.1 contains a Groundwater Quality discussion that compares regional groundwater sampling and analysis results to national drinking-water standards. Section 3.1.4.2.2 includes a discussion of Saturated Zone Groundwater Quality that summarizes water chemistry for the volcanic and carbonate aquifers (Table 3-18) and the results of groundwater sampling and analysis for radioactivity (Table 3-19). This information establishes a baseline for the quality and characteristics of area groundwater.

7.5.3.2 (2760)
Comment - EIS000897 / 0001
What scenarios will be used for future groundwater use in the area, and why were they selected?

Response
DOE assumed that this comment is asking about the groundwater-use scenario used to assess impacts related to the long-term performance of the proposed repository, as discussed in Chapter 5 of the EIS. Section 5.4 describes the exposure scenario for an individual having a diet and lifestyle representative of the current residents of Amargosa Valley, at 18 kilometers (11 miles) from the repository. The scenario assumed that this individual would "…grow half of the foods that the individual would consume on the property, irrigate crops and water livestock using groundwater, and would also use groundwater as a drinking water source and to bathe and wash clothes." DOE developed this scenario because it represents the highest exposure that could reasonably be expected for a resident of the Amargosa Desert area.

The analyses described in the Final EIS are based on the individual exposure scenario specified by the Environmental Protection Agency in their regulations at 40 CFR Part 197, *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada*. In this case, the regulation calls the hypothetical individual the "reasonably maximally exposed individual" and describes this individual as a person who would live at a point of maximum contaminant concentration about 18 kilometers (11 miles) from the repository site. This person would have a diet and living style representative of people now living in Amargosa Valley and would drink 2 liters (0.5 gallon) of water per day from wells tapping the groundwater at the person's residence. The EIS also addresses the scenario for a groundwater protection standard, which is another requirement established in 40 CFR Part 197. In this case though, specific water standards would be met by a segment of groundwater that the regulation identifies by volume (that would be used annually by a hypothetical community) and location (with respect to the groundwater flow path from Yucca Mountain).

7.5.3.2 (3281)
Comment - EIS001107 / 0002
The Draft EIS is deficient in its analysis of the potential impact of a release of radioactive materials into the groundwater. The Draft EIS states "[t]he groundwater flow system of the Death Valley region is very complex, involving many aquifers and confining units. Over distance, these layers vary in their characteristics or even their presence. In some areas confining units allow considerable movement between aquifers..." Draft EIS, 3.1.4.2.1. The Draft EIS continues to discuss scientific disagreements over the groundwater flow around Yucca Mountain, and to state that "additional research is needed to resolve the issues." Draft EIS, 3.1.4.2.2. The Draft EIS concludes that "[n]atural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, and spring discharge in Death Valley is a possibility." Draft EIS, 5.3 (emphasis added). The geologic repository proposed will contain the majority of the United States' radioactive waste, basic questions regarding where groundwater from the site will travel should not be couched in uncertainties.

Response
DOE believes there is little uncertainty about the southerly flow of groundwater from Yucca Mountain to the Amargosa Desert, then to the primary discharge point at Alkali Flat (Franklin Lake Playa). The EIS description of this flowpath often includes words such as "general," "most," and "primary" because not all of the flow discharges at Alkali Flat. For example, a small amount of the groundwater from Yucca Mountain that mixes with the large groundwater reservoir in the Amargosa Desert might move to the southwest through fractures in relatively impermeable Precambrian rocks at the southeastern end of the Funeral Mountains. In addition, a small amount of the flow reaching Alkali Flat remains as groundwater and provides underflow to southern Death Valley. The component of flow to the southwest would either discharge in springs near Furnace Creek Ranch or continue to move as groundwater toward the Death Valley saltpan. With regard to the main flow to the south, groundwater moving past Alkali Flat moves toward discharge and evapotranspiration locations in the Shoshone-Tecopa area. Chapter 5 summarizes the proposed repository's long-term performance, which includes projected effects at several distances from the Yucca Mountain site along the primary groundwater flowpath (Yucca Mountain to Amargosa Desert to Alkali Flat). There is no reason to suspect that any of the possible branches to this flowpath could experience greater impacts.

7.5.3.2 (3499)
Comment - EIS001521 / 0010
Page S-41, second paragraph--Again, the three ground-water sub-basins are not part of the Death Valley ground-water basin but are divisions of a subset of that basin, the Central Death Valley ground-water subregion.

Response
DOE agrees that the subregion, basin, and section labels are not clear, and has changed them to be consistent with *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California* (DIRS 100131-D'Agnese et al. 1997), which is the main source for this information in Section S.4.1.4 and Section 3.1.4.2.1 in the EIS.

7.5.3.2 (3502)
Comment - EIS001521 / 0009
Page S-40, Figure S-19--(Legend) "Subregion boundary" should be labeled as the "Central Death Valley Subregion boundary" and the subregion should be defined in the text; "Ground-water basins and sections" should be labeled

"Ground-water sub-basins and sections" and defined hydrogeologically in the text; Pahute Mesa-Oasis Valley Ground-Water Basin should be designated as a sub-basin (as well as the other two sub-basins); and Jackass Flats appears to be part of the Specter Range section and not part of the Fortymile Canyon section. What is a ground-water section? The term is not defined in the Summary text, or anywhere else in the DEIS for that matter. Do sections equate to the State of Nevada's hydrographic areas? According to the referral to the Jackass Flats area (page S-41, fifth paragraph), they do not equate.

Response
DOE agrees that the subregion, basin, and section labels are not clear, and has changed them to be consistent with *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California* (DIRS 100131-D'Agnese et al. 1997), which is the main source for this information in Sections S.4.1.4 and 3.1.4.2.1 in the EIS. The flow in each subregion has clearly defined paths; for convenience, the subregions were subdivided into basins and sections. These boundaries are for descriptive purposes only and do not define discrete independent flow systems (DIRS 100131-D'Agnese et al. 1997). The groundwater flow subregion, basin, and section terminology used in D'Agnese et al. (DIRS 100131-1997) is not the same as that used in State of Nevada water appropriations, which is based on topographic divides. DOE has clarified that distinction in Section 3.1.4.2.1. A new figure shows the relationship between the Death Valley region and subregions.

7.5.3.2 (3522)
Comment - EIS001150 / 0002
Possible ground water contamination in the event of an earthquake, corrosion of casks, etc.

Response
DOE has conducted an extensive site characterization program at Yucca Mountain to evaluate the effects of existing faults and additional faulting on the groundwater flow and transport system. In addition, DOE has performed extensive analyses on the design of the waste packages.

The waste-emplacement areas would be away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide releases. Additional fault displacements from post-emplacement seismic activity probably would be on existing fault planes. Calculations show that there would be almost no effect on repository performance from rockfalls.

A fault-fracture flow system is the basis for the hydrology models. This model is derived from extensive studies conducted at Yucca Mountain. The addition of new faults and associated seismic events would have very minor or no effect on the current fault- and fracture-flow pathways and, therefore, would be unlikely to alter repository performance. Analysis of long-term repository performance shows that the combination of the site's natural and engineered barriers would keep radionuclides well below the regulatory limits established at 40 CFR Part 197. EIS Sections 3.1.3 and 3.1.4.2.2 contain more information.

Because the repository would be above the water table in the unsaturated zone, the most important process controlling waste package corrosion would be whether water would drip from seeps onto the waste packages. Field and laboratory testing indicate that seepage would be limited and the locations of the seeps would depend on fracture-matrix and drift-wall interactions. Under the present design, radioactive waste in the repository would be enclosed in a two-layer waste package and covered by a titanium drip shield. The waste package would have a chromium-nickel-alloy (Alloy-22) outer layer and a stainless-steel inner layer. These materials have extremely low corrosion rates and would be unlikely to fail for thousands of years. Section I.2.4 contains more information.

7.5.3.2 (4038)
Comment - EIS001513 / 0001
There is a lot of uncertainty surrounding the future of Yucca Mountain. So many questions remain about its geology. There is known seismic activity in the area. Recent studies reveal that groundwater may move faster than previously thought. There may also be more volcanic activity than previously thought. Many questions remain about Yucca Mountain. Before we store 70,000 tons of nuclear waste, we must give all of these issues more attention.

Response

Regarding the inherent uncertainty associated with geologic and hydrologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 of the Draft EIS explains how DOE dealt with these issues.

Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 of the Draft EIS describes the impacts from accident scenarios associated with earthquakes during operation of the repository. Several sections in Chapter 5 of the Draft EIS consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on geology, geologic hazards, and the effects of these hazards on the repository, have been adequately described and analyzed in the EIS.

As part of its site characterization program, DOE has used a variety of naturally occurring isotopic indicators, one of which is chlorine-36, to investigate the nature of infiltration and deep percolation of water at the site. Results from this program indicate elevated amounts (values above normal background measurements) of “bomb-pulse” chlorine-36 from nuclear testing during the 1950s and 1960s. Detection of this “bomb-pulse” chlorine-36 in the subsurface at Yucca Mountain generally associated with faults and well-developed fracture systems close to these faults.

Detection of elevated levels of chlorine-36 could be evidence of a connected pathway through which surface precipitation has percolated to depth within the last 50 years.

These results, however, must be viewed in their proper context regarding the question of whether waste can be stored safely at Yucca Mountain. Overall, most of the water that infiltrates into Yucca Mountain moves much more slowly through the matrix and fracture network of the rock. Only a small fraction has moved through the connected portion of the fracture network with relatively fast travel times. Carbon isotope data from water extracted from the matrix correspond to residence times as long as 10,000 years.

The elevated values of bomb-pulse chlorine-36 detected in the subsurface correspond to increases of between about two to eight times the amount of naturally occurring background chlorine-36. This background signal is the amount observed in the regional aquifers and the matrix waters of rocks in the unsaturated zone. Furthermore, even elevated bomb-pulse values represent exceedingly minute increases in the amount of chlorine-36. Naturally occurring ratios of radioactive chlorine-36 to the other isotopes of chlorine (chlorine-35 and -37) are on the order of one chlorine-36 atom to approximately 2 trillion other chlorine atoms. Their detection is more a tribute to the precision of the analytical methods used in this study (accelerator mass-spectrometry) than it is an indication of an unsuitable environment for the emplacement of high-level radioactive waste. To ensure the correct interpretation of this subtle chemical signal, studies are under way to determine if independent laboratories and related isotopic studies can corroborate this detection of elevated amounts of chlorine-36.

Another important factor regarding the safety of emplaced waste concerns whether percolating water would actually come in contact with waste packages. The process of drift excavation creates a capillary barrier that would cause the diversion of percolating water around the drift opening, further reducing the amount of water potentially capable of contacting waste packages. DOE is conducting a series of experiments to determine the seepage threshold, which is the amount of water necessary to overcome the capillary barrier caused by excavation. Results to date suggest that the amounts of percolating water at the waste-emplacement level could be insufficient to exceed the existing capillary barrier.

Additional evidence to the overall lack of observable fluid flow in the subsurface is the fact that throughout the excavation of more than 11 kilometers (6.8 miles) of tunnels (Exploratory Studies Facility and cross drifts) and testing alcoves, only one fracture was moist. No active flow of water was observed. Further observations from testing alcoves that are isolated from the effects of tunnel ventilation for several years confirm the lack of observable natural seepage at the repository level. In summary, despite encountering millions of fractures in the course of excavation activities, there is scant evidence that even modest quantities of water penetrate to the depth of the waste-emplacement horizon.

7.5.3.2 (4044)
Comment - EIS001524 / 0004
The DEIS is inconsistent when it states that water flows at highly variable rates through the saturated zone of Yucca Mountain because it states earlier that the amount of water affected would be minimal due to low rate of flow (Section 5.2.3.1). By assuming a low flow rate (despite mentioning later that rates were variable), the DEIS underestimated the potential amount of seepage that could occur into the repository (DEIS, p. 5-10).

Response
DOE agrees that the discussion in the Draft EIS may be confusing and warrants clarification. The first part of the paragraph is intended to describe how the number of seeps that flow into drifts, and the amount of water that they would carry, are limited by the small amount of water moving through the mountain. That is, the only source of the seepage is infiltration from surface precipitation and Yucca Mountain is in a warm, semiarid climate. The statement at the end of the paragraph describes how the time it takes for percolating water to move through the unsaturated zone is highly variable ("...less than 100 years to thousands of years…"). Use of the terminology "rate at which water flows" in the first statement did not provide a clear enough description of a quantity rate (amount per time) as intended. Accordingly, it has been changed to indicate the "small quantity of water flowing through". DOE believes that the amount of water included in modeling efforts as moving through the unsaturated zone at Yucca Mountain is consistent with results of numerous field measurements and studies and the portion of that water predicted to actually seep into the drifts is conservatively high. The commenter is referred to the *Total System Performance*

Assessment – Viability Assessment (DIRS 101779-DOE 1998, Vol. 3) for a more detailed discussion on infiltration and seepage into drifts.

7.5.3.2 (4145)
Comment - EIS001199 / 0003
As evidenced in the experimental boreholes made for possible use in deep in ground storage, radioactive material from the above ground nuclear testing was found. The highly radioactive nuclear materials do not have to be water soluble, for even very, small radioactive particles can be transported in the flow of water in the underground water table.

What may be worse is that an earthquake at Yucca Mountain could cause groundwater to surge into the storage area, forcing dangerous amounts of plutonium into the atmosphere and contaminating the water supply. This is not an unlikely scenario, given that the area is a seismic minefield. Over the last 20 years, more than 621 earthquakes have been recorded in the area, at a magnitude of 2.5 or higher.

According to an article in a recent Chemical & Engineering News, where it was previously believed that plutonium in the stable oxide is exclusively Pu(IV), the present work shows that Pu02 can exist in a much higher oxidative state. It is suggested that more than 25% of plutonium atoms are actually in the Pu(VI) state.

A key factor in favor of burying plutonium waste was supposedly the highly insoluble nature of Pu(IV) compounds. In light of the fact that the Pu(VI) species does exist, and is more soluble in water, it will therefore be more mobile in geological environments. Thus, the safety of this storage plan needs to be reconsidered.

Response
DOE agrees with this comment that nuclear-bomb era (post-1952) radionuclides appear to have reached the waste emplacement horizon at Yucca Mountain, as described in Section 3.1.4.2.2 of the EIS. With respect to the transport of insoluble contaminants in groundwater as colloidal particles, this phenomenon is described in Section 3.1.4.2.2 for the colloidal transport of plutonium from an underground detonation site on Pahute Mesa at the Nevada Test Site.

Additional research is addressing the relative magnitude of radionuclide migration by colloidal versus dissolved transport (particularly for plutonium) and definition of the effect of variation in the geochemical environment on colloid stability and transport. In addition, the reversibility of colloid sorption (the conditions in which colloids can bind or release radionuclides) is being analyzed.

7.5.3.2 (4264)
Comment - EIS001521 / 0013
Page S-66, Table S-1--Water demand values listed under Hydrology (ground water and surface water), of 250 to 480 acre-feet per year, are not the same as those listed for the Jackass Flats hydrographic area on page 3-40, Table 3-11, footnote f, of Volume 1 (300 acre-feet for the eastern third of the area and 580 acre-feet for the western two-thirds). Where did the 250 to 480 acre-feet values come from? Revise for consistency.

Response
The information in Table S-1 of the Draft EIS is misleading. DOE has revised the short-term impact entry for Hydrology. Tables 2-7 and 8-5 reflect this change.

The "250 to 480 acre-feet values" from the Draft EIS represent the range of expected water demand for the repository during the operational period, and not the perennial yield values. Section 4.1.3.3 of the EIS discusses the projected water demand.

7.5.3.2 (4344)
Comment - EIS001191 / 0007
DOE's own data shows that Yucca Mountain will fail to contain the waste.

- The presence of water within the proposed repository that is of recent origin (less than 50 years) indicates that ground water is percolating through the mountain at a rate that violates the DOE's own standard for an acceptable repository site.

- At least 33 seismic faults lie close to, or within, the site. 621 earthquakes of magnitude 2.5 or greater have occurred within 50 miles of the site over the last 20 years, including a 5.6 level quake centered just 12 miles from the site in 1992. A magnitude 5 or 6 earthquake at the site could dramatically raise the water table beneath the repository, flooding the chamber and leading to a corrosive breakdown of the disposal canisters and a possible steam explosion, thereby releasing plutonium and other waste products into the air and ground water.

Response
DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, which considered the effects of future seismic and volcanic activity, changes in the climate, and fast-path fractures extending from the surface to the water table, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

DOE agrees that evidence of nuclear-age water reaching the level of the proposed repository, along with other data collected at the site, has shown that water movement through rock fractures and faults is an important component of the site's long-term performance. Modeling of the long-term performance of the repository shows that the rate of radionuclide travel from the repository would be in compliance with the radiation protection standards in 40 CFR Part 197. Accordingly, DOE believes that the predicted releases of radionuclide from the repository would not be considered significant.

DOE recognizes there is a significant seismic hazard at Yucca Mountain, but with proper design, a repository can operate safely over the long term. The possibility of groundwater rise and repository inundation is remote because no credible mechanism is known that can account for such a rise in groundwater to the elevation of the emplaced waste. Szymanski (DIRS 106963-1989) proposed that during the last 10,000 to 1 million years, hot mineralized groundwater was driven to the surface by earthquakes and volcanic activities and deposited calcite and opal at Yucca Mountain. This hypothesis goes on to suggest that similar forces could raise the regional groundwater in the future and inundate the emplacement horizon.

To investigate this hypothesis further, DOE requested that the National Academy of Sciences conduct an independent evaluation. The Academy concluded in National Research Council (DIRS 105162-1992) that no known mechanism could cause a future inundation of the repository horizon. The geologic evidence indicates that groundwater never reached the repository horizon; in fact, the largest rise seems to have been about 120 meters (390 feet) during the last several million or more years. Based on simulations of earthquake effects, the predicted water table rise could be about 20 meters (66 feet) at most. The 1992 Little Skull Mountain earthquake raised water levels in some monitoring wells by a maximum of less than 1 meter.

Dublyansky (DIRS 104875-1998) proposed another line of data in support of the warm water upwelling hypothesis. That study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. It concluded that some crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of independent experts, including scientists from the U.S. Geological Survey, did not concur with Dublyansky's conclusions. DOE disagrees with the central conclusions in Dublyansky's report, but has supported continuing research by the University of Nevada, Las Vegas. See Section 3.1.4.2.2 of the EIS for more information.

7.5.3.2 (4503)
Comment - EIS001455 / 0004
By now, everyone knows that under the site at Ward Valley, where the government wanted to dump "low level" radioactive waste, is the largest groundwater aquifer in the state, containing an estimated thirty million acre feet of water. But how did that water get there? The Native Americans, who have been there for thousands of years, say the Amargosa River, which the E.I.S. sloughs off as if it is meaningless because it is mostly a dry river bed, used to be above ground. It went underground during a massive earthquake, which made a big crevasse, and caused the river to sink, and water to be trapped in the rock formations beneath the ground. And the report is correct—the groundwater flow system is very complex, and there is scientific uncertainty about the groundwater flow boundaries. To put it correctly, they don't have a clue where that water runs underground, and how the emissions from the buried nuclear waste is going to migrate underground.

Forked-tongued talk, like "the depth to groundwater and the arid environment would combine to reduce the potential for meaningful contaminant migration" (at P. S-41) is meaningless and deceitful. What is a meaningful contaminant migration?

Response
The geology/hydrology of Ward Valley is outside the scope of the Yucca Mountain EIS. However, the commenter should compare information on Ward Valley to available information on the Central Valley of California.

The Native American oral history cited by the commenter might reflect an ancient seismic event that affected the Amargosa River. However, the groundwater that occurs in the aquifers beneath the Yucca Mountain site originated as precipitation, recharge, and infiltration in areas (see Section 3.1.4.2 of the EIS). The groundwater modeling technique utilizes probabilistic methods to account for the complexities of the groundwater system and uncertainties in both data and processes.

The EIS does not say there would be no groundwater contamination under the proposed repository at Yucca Mountain. Chapter 5 of the EIS describes the long-term performance of the proposed repository, and predictions of impacts from radioactive and nonradioactive materials released to the environment during the first 10,000 years after repository closure. The primary means, or pathways, by which these materials would become available, over time, to humans and the environment include gradual container failure and leaching of contaminants through the unsaturated zone beneath the repository, then to the groundwater. DOE believes it has learned about contaminant migration as a result of its experience at other waste-management facilities. In addition, the Yucca Mountain characterization effort has centered (and continues to center) around learning enough about the site to make reasonable projections about how and when contaminants would move should the proposed repository action take place.

Section 5.7 of the EIS presents results of analyses performed for "what-if" scenarios. These evaluations include looking at potential impacts from disruptive events such as human intrusion (by drilling) and volcanic and seismic disturbances. The long-term performance analysis includes looking at much wetter climates than exist today at Yucca Mountain and the potential effects on radionuclide transport.

DOE uses the term "meaningful contaminant migration" to indicate a level of radionuclide release and transport that would result in adverse health effects to the individual receptor (see Chapter 5 of the EIS).

7.5.3.2 (4523)
Comment - EIS001521 / 0007
Page S-39, sixth paragraph--(Ground Water) By definition, confining units "do not" allow considerable (ground-water) movement between aquifers. If they do, they are not confining units. The term "aquitards" should be used when and where ground water moves through lowly-permeable units.

Response
DOE agrees that, technically, a confining unit does not allow "considerable movement" between aquifers. In some areas in the Death Valley region these units allow considerable water movement, and normally would be called aquitards. However, these units are sufficiently confining to support artesian conditions over much of their distribution in the regional basin.

7.5.3.2 (4524)
<u>Comment</u> - EIS001521 / 0008
Page S-39, seventh paragraph, and page S-41, first paragraph--The Amargosa Desert is not shown on page S-40, Figure S-19. Also, the relationship between the Death Valley ground-water basin, the Central Death Valley Subregion, and the three sub-basins should be clarified. Is it the Alkali Flat-Furnace Creek "Ranch" ground-water sub-basin or the Alkali Flat-Furnace Creek ground-water sub-basin (page S-40, Figure S-19)?

<u>Response</u>
In Summary Section S.4.1.4 and in Section 3.1.4.2.1 of the EIS, DOE has added "Amargosa Desert" to the groundwater basin figure and has added a new figure to show the Death Valley Regional Groundwater System and the three subregion boundaries. The correct title is "Alkali Flat - Furnace Creek groundwater sub-basin"; "Ranch" has been deleted.

7.5.3.2 (4525)
<u>Comment</u> - EIS001521 / 0038
Page 3-39, second paragraph--According to page 3-38, Figure 3-13, Fortymile Canyon lies within the Alkali Flats-Furnace Creek Ranch ground-water sub-basin, yet it is not mentioned here. This is a very important hydrogeologic feature and should be emphasized.

<u>Response</u>
The comment is correct. DOE has added the Fortymile Canyon Section to the text in Section 3.1.4.2.1.

7.5.3.2 (4526)
<u>Comment</u> - EIS001521 / 0039
Page 3-39, third paragraph--Reference the "one numerical model for infiltration" statement and justify the use of an average rate versus analyzing end members of a range of values. Also, the "in comparison" sentence should provide referenced values, or there is nothing to compare.

<u>Response</u>
The statement was attributed to one of the two references listed at the beginning of Section 3.1.4 of the Draft EIS. Since publication of the Draft EIS, DOE has updated the reference materials for this discussion. The reference for the statement identified in the comment is the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Table 8.2-9). In response to this and other comments, DOE has added specific citations to Section 3.1.4.

The paragraph in question states that recharge in the local Yucca Mountain area is small in relation to other areas contributing to the same groundwater flow, and provides a simple basis for that statement. That is, other areas in the vicinity have both higher precipitation and higher infiltration rates. DOE believes more detail (such as ranges of infiltration estimates and precipitation for Yucca Mountain and for other areas in the vicinity, as well as comparative surface areas) is not necessary to justify the statement. Such detail would, in fact, make the explanation more complicated than necessary. In addition, Section 3.1.4.2.2 contains a more detailed discussion of infiltration rates at Yucca Mountain.

7.5.3.2 (4529)
<u>Comment</u> - EIS001521 / 0042
Page 3-39, sixth paragraph--Again, the "Central Death Valley" designation is for a ground-water sub-region, not a ground-water basin.

<u>Response</u>
DOE agrees that the subregion, basin, and section labels are not clear, and has changed them to be consistent with *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California* (DIRS 100131-D'Agnese et al. 1997), which is the main source for this information in Sections S.4.1.4 and 3.1.4.2.1 in the EIS. The flow in each subregion has clearly defined paths; for convenience, the subregions were subdivided into basins and sections. These boundaries are for descriptive purposes only and do not define discrete independent flow systems (DIRS 100131-D'Agnese et al. 1997). The groundwater flow subregion, basin, and section terminology used in D'Agnese et al. (DIRS 100131-1997) is not the same as that used in State of

Nevada water appropriations, which are based on topographic divides. DOE has clarified that distinction in Section 3.1.4.2.1. A new figure shows the relationship between the Death Valley region and subregions.

7.5.3.2 (4530)
Comment - EIS001521 / 0043
Page 3-40, first paragraph--If hydrographic areas are finer divisions of basins and/or sub-basins, define them hydrologically. Also, the hydrographic areas are not consistent with locations shown on page 3-38, Figure 3-13, because they are not even shown on the figure. Reference water-use withdrawal amounts listed throughout the paragraph. Define Devil's Hole and why it is important.

Response
DOE agrees that the subregion, basin, and section labels are not clear, and has changed them to be consistent with Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California (DIRS 100131-D'Agnese et al. 1997), which is the main source for this information in Summary Section S.4.1.4 and Section 3.1.4.2.1 in the EIS. The flow in each subregion has clearly defined paths; for convenience, the subregions were subdivided into basins and sections. These boundaries are for descriptive purposes only and do not define discrete independent flow systems (DIRS 100131-D'Agnese et al. 1997). The groundwater flow subregion, basin, and section terminology used in D'Agnese et al. (DIRS 100131-1997) is not the same as that used in State of Nevada water appropriations, which are based on topographic divides. DOE has clarified that distinction in Section 3.1.4.2.1. A new figure shows the relationship between the Death Valley region and subregions.

DOE has added the Devils Hole Protective Withdrawal to the EIS text. Section 3.1.5.1.3 describes the special status species in the Ash Meadows/Devils Hole Protective Withdrawal.

7.5.3.2 (4531)
Comment - EIS001521 / 0044
Page 3-49, Table 3-11--The low end of the Jackass Flats hydrographic area "perennial" yield estimate is 880 acre-feet per year; yet on page S-41, Section S.4.1.4 Hydrology, of the Summary, fifth paragraph, that number is given as 890 acre-feet--which is correct?

Response
The correct Jackass Flats hydrographic area perennial yield estimate is 880 acre-feet (1,085,000 cubic meters) per year. DOE has changed the number in Summary Section S.4.1.4.

7.5.3.2 (4532)
Comment - EIS001521 / 0045
Page 3-41, first paragraph--The comment about the usage of acre-feet should have come earlier in the chapter as it has already been used several times (on page 3-37, for example).

Response
It is standard practice in DOE EISs to present numerical values in metric units with corresponding English unit conversions in parentheses. The paragraph in question, which is immediately after Table 3-11, describes the use of acre-feet in that table because it is the first instance in that section to present water quantities in English units only (because it is the commonly understood term to describe such quantities). DOE believes that this deviation from the standard practice warranted an explanation. "Acre-feet" is defined in the Glossary and in standard dictionaries, so there should be little confusion.

7.5.3.2 (4533)
Comment - EIS001521 / 0046
Page 3-41, second paragraph--(Ground-Water Quality) Programs that sample ground water for water-quality purposes are mentioned but no generalized information about the results are listed. Even though more detailed results concerning the subject are given in subsequent sections of Chapter 3 for the Yucca Mountain area, because this discussion is about regional hydrological aspects, generalized water-quality descriptions of the ground-water sub-basins should be listed, if available.

Response
The second paragraph of the Groundwater Quality discussion in Section 3.1.4.2.1 of the EIS (which follows the paragraph identified in the comment) presents generalized water quality descriptions for the Yucca Mountain region. It focuses on the water quality of the area downgradient from Yucca Mountain (that is, the Amargosa Desert area). Because this is the regional groundwater that the repository could eventually affect, the EIS describes the baseline water quality by comparing the analytical results of sampling groundwater and springs in this region to the most widely recognized standards for water quality: the Environmental Protection Agency's drinking-water standards. To be brief, the discussion states that the sampled locations "...met primary drinking water standards, but that a few sources exceeded secondary and proposed standards." Then it identifies the specific parameters exceeded. The source of the information (DIRS 104828-Covay 1997) contains additional detail. In addition, Section 3.1.4.2.2 of the EIS discusses radiological parameters in groundwater samples.

7.5.3.2 (4534)
Comment - EIS001521 / 0047
Page 3-41, 3.1.4.2.2 Ground Water at Yucca Mountain; Unsaturated Zone, first paragraph--(Water Occurrence) Given that the perched-water bodies contain young water, as compared to pore-space water, and the attitude of the geologic units is dipping downward into a fault plane, could it be that the perched water exists merely by the fact that faulting off-set of a somewhat incompetent unit (like the Calico Hills nonwelded unit) creates a lowly-permeable fault "gouge" (or fill) that prevents further movement of water down that fault plane? In time, the Calico Hills nonwelded unit underlying the perched-water body will become saturated and drain off the perched water down-dip toward the fault plane (unless there is substantial and constant source of recharge to sustain the perched-water body). Therefore, the presence of the perched water indicates that there may be significant amount of lowly-permeable fault gouge associated with this faulted system. Perhaps too much importance is being placed on the perching unit (layer).

Response
The scenario for the origin of the perched water described in the comment is reasonable and consistent with the general scenario identified under the Yucca Mountain project. The description is also very similar to the scenario described in the last paragraph of the Water Source and Movement discussion under Section 3.1.4.2.2 of the EIS. See Striffler et al. (DIRS 104951-1996) for additional information on the several different scenarios that could result in the accumulation of perched water in the subsurface formations at Yucca Mountain.

The discussion of perched water in the EIS reflects the emphasis placed on this phenomenon in the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) from which the description in the EIS was abstracted. The Site Description places considerable importance on perched water in conceptual models of flow in the unsaturated zone.

Section 3.1.4.2.2 of the EIS does not judge the importance of the perched water that has been found at Yucca Mountain. But DOE does believe that it is important from the standpoint of full disclosure to describe these water bodies. Also, as identified in the EIS, dating of perched water has aided DOE's understanding of water movement along faults and fractures in the subsurface.

7.5.3.2 (4536)
Comment - EIS001521 / 0049
Page 3-44, Table 3-12--Provide permeability information for all described hydrogeologic units to coincide with hydrologic discussion on previous pages. Also, only effective-porosity values are meaningful in determining water movement through sub-surface units--are these effective-porosity estimates? If not, they should be replaced with the appropriate estimates. The description of the Calico Hills nonwelded unit should include the basal vitrophyre and nonwelded tuffs of the Topopah Spring Tuff (as shown on page 3-45, Figure 3-15). This is important because later discussions (page 3-47, third paragraph) suggest that the basal vitrophyre and nonwelded tuffs of the Topopah Spring Tuff may or may not be the perching layer.

Response
Table 3-12 pertains to the unsaturated zone, in which water flow is vertical and mainly through fractures. Permeability data on the unsaturated zone consist mainly of tests of saturated permeability measurements for cores, which would provide little information on water flow in the unsaturated zone. The more significant data with

respect to movement of water in the unsaturated zone includes matrix saturation and hydraulic potential for which a large database exists, and is used in modeling unsaturated flow. Matrix saturation is included in Table 3-12 of the Draft EIS (Table 3-13 in the Final EIS), but hydraulic potential does not lend itself to simple tabulation. Effective porosity was not measured in the U.S. Geological Survey testing of some 4,900 core samples from the unsaturated zone (see DIRS 100033-Flint 1998).

The last part of this comment suggests that the "basal vitrophyre and nonwelded tuffs" of the Topopah Spring Tuff be specifically identified as part of the Calico Hills nonwelded unit in Table 3-12 of the Draft EIS. The primary sources of information for this table are Flint (DIRS 100033-1998) and Montazer and Wilson (DIRS 100161-1984). The description of the Calico Hills nonwelded unit in Table 3-12 of the Draft EIS identifies four subunits and notes that zeolites occur in the lower three subunits. Tracing the information back to the primary sources, the top subunit of the four is the basal portion of the Topopah Spring Tuff. To simplify the presentation, this level of detail is not included in the table. Moreover, Figure 3-15 of the Draft EIS (Figure 3-17 in the Final EIS) shows the vitrophyre and nonwelded tuffs at the base of the Topopah Spring Tuff as included in the upper volcanic confining unit. Flint (DIRS 100033-1998) and Montazer and Wilson (DIRS 100161-1984) provide more detail on the hydrogeologic units at Yucca Mountain.

7.5.3.2 (4537)
Comment - EIS001521 / 0050
Page 3-44, second paragraph--(Water Source and Movement) Range values should be used as well as the average. Using the high-end of the infiltration range of 3 inches per year would have an order of magnitude difference (when considering the resultant consequences on the stability of waste in the repository) as compared to an average of 0.3 inch. Water volumes would be much greater, and the amount of time to reach a relevant sub-surface horizon much less.

Response
DOE used numerical data from the reference cited in the subsection (DIRS 100147-Flint, Hevesi, and Flint 1996) to illustrate the temporal and spatial variability of net infiltration in the vicinity of Yucca Mountain. Flint, Hevesi, and Flint (DIRS 100147-1996) developed conceptual and numerical models of net infiltration on the basis of analyses of field-moisture profile measurements at 99 neutron boreholes over an 11-year period (1984 to 1995). Thus, the infiltration models, which serve as inputs to models of recharge to the saturated zone, are based on qualitative and detailed quantitative measurements in different topographic/geologic terrains. The ranges and average values of net infiltration cited in the EIS summarize the results of this numerical modeling.

DOE believes that Flint, Hevesi, and Flint (DIRS 100147-1996) and the Site Description (DIRS 151945-CRWMS M&O 2000), which is now also referenced in this discussion, explain the data in sufficient detail and that the EIS does not require additional explanation.

7.5.3.2 (4538)
Comment - EIS001521 / 0051
Page 3-45, Figure 3-15--There is no mention of the areal extent of the hydrogeological unit QTc, valley-fill confining unit. Does it underlie QTa, valley-fill aquifer, in many, most, or all places? Also, "uva, Upper volcanic" should have "aquifer" added to the name.

Response
The subsurface extent of the QTc unit is not well established, and DOE has modified the "Comments" column in Figure 3-15 of the EIS accordingly. In addition, DOE has changed the heading for the "uva" unit in Figure 3-15 to "Upper volcanic aquifer."

7.5.3.2 (4539)
Comment - EIS001521 / 0052
Page 3-46, first and second paragraphs--The discussion of water movement through the unsaturated zone via fault-plane pathways is the over-riding reason for including the high-end range value for infiltration, and the possible movement of water to and through a proposed repository block (see Volume I, comments number 36 in this review). Yucca Mountain is resident to many prominent faults (especially for the expanded area of the l-t-l build-out blocks),

and an assessment of the Mountain's appropriateness for use as a viable site for radioactive-waste disposal must include a probable high-end analysis.

Response
Chapter 3 of the EIS describes the nature of the environment that would be affected by the Proposed Action. Using average values in Chapter 3 to describe characteristics such as infiltration does not exclude using a range of values to describe impacts in other parts of the EIS. Chapter 5 of the EIS discusses the specific manner in which modeling was conducted and the parameters that were used. Section 5.2.3 is of particular relevance to this comment as it describes the analyses performed to model infiltrating water through the unsaturated and saturated zones. This section also describes how wetter climates were considered in modeling long-term performance of the repository.

7.5.3.2 (4540)
Comment - EIS001521 / 0053
Page 3-47, second paragraph, third bullet--Explain why the 10-foot soil depth over a fracture is important. If the soil horizon is already saturated prior to a precipitation event, the residence time of infiltrating water in that soil horizon may be minimal before a fault plane is encountered. In addition, a 10-foot thick soil in this environment would be somewhat unusual; or are we discussing alluvial, colluvial, or other surficial deposits here?

Response
Where soil thickness exceeds 3 meters (10 feet), infiltration of surface water and nuclear-age chlorine-36 at Yucca Mountain is negligible. This is because soil zones thicker than 3 meters (10 feet) retain infiltrating moisture sufficiently long so that evapotranspiration recycles it to the atmosphere. In this context, DOE used the term "soil" to include alluvial, colluvial, and eolian deposits (DIRS 100147-Flint, Hevesi, and Flint 1996).

The source of the 3-meter (10-foot) soil-depth criterion is CRWMS M&O (DIRS 104878-1998). That report cites an earlier report (DIRS 100144-Fabryka-Martin et al. 1997) as the basis for the three criteria, including soil depth.

DOE does not believe that the EIS requires more information.

7.5.3.2 (4541)
Comment - EIS001521 / 0054
Page 3-47, third paragraph--The statement, "...low-permeability zeolite zones impede the vertical flow of water near (the base of) the Topopah Spring welded unit and its contact with the underlying Calico Hills nonwelded unit, forming perched-water bodies," suggests that the perching-zeolitic zone is within the basal part of the Topopah Spring welded unit, and not the basal vitrophyre and nonwelded tuffs of the Topopah Spring Tuff (which is the upper part of the Calico Hills nonwelded hydrogeologic unit, see page 3-45, Figure 3-15). Please clarify the sub-surface location of the perching unit. Also, after clarification, this statement should come earlier in Chapter 3 where perched-water bodies are first mentioned (see the Unsaturated Zone, Water Occurrence discussion on pages 3-41 and 3-42).

Response
The comment refers to a statement in the subsection on Water Source and Movement in Section 3.1.4.2.2 regarding the occurrence of perched, saturated water bodies within the unsaturated zone at Yucca Mountain.

As explained in the Yucca Mountain Site Description (see reference in Section 8.5.2), the majority of perched water bodies were found in formations overlying relatively impermeable matrix material, such as the Topopah Spring basal vitrophyre. Although the vitrophyre is extensively fractured, in many locations the fractures have been filled with clays and zeolitic materials that impede vertical flow. At borehole SD-7, and possibly elsewhere, portions of the Calico Hills unit have been extensively altered to zeolites to create perched water bodies. Thus, either the basal vitrophyre of the Topopah Springs Tuff or the underlying Calico Hills Formation can cause perching depending upon the local degree of alteration. As both stratigraphic units may be of very low permeability, it is not always clear which forms the perching horizon, and the issue may not be of great importance.

In order to avoid confusion, the cited statement in the EIS has been revised.

Regarding the suggestion to move text on p. 3-47 forward to p. 3-42, DOE does not believe this would be appropriate.

7.5.3.2 (4542)
Comment - EIS001521 / 0055
Page 3-48, Table 3-13--From which hydrogeologic unit was the analyzed pore water collected? This water-quality comparison is meaningful for only those units near and connected with the perched-water bodies. Was pore water collected from the Calico Hills nonwelded unit, beneath a perched-water body (if doable)? This would help determine if the perched water is moving down through the unit and "down dip" towards the fault plane where a higher degree of remobilization may occur.

Response
According to the source of Table 3-13 (DIRS 104951-Striffler et al. 1996), the perched water samples came from boreholes NRG-7A, SD-9, UZ-14, SD-7, and UZ-1; the pore water samples came from four zones of UZ-14 between depths of 383.7 and 464.7 meters (1258.8 and 1,524.6 feet). Striffler et al. (DIRS 104951-1996) reports that perched water was found at a depth of 381 meters (1,250 feet) in UZ-14 and limited flow was observed to about 465 meters (1,526 feet). Thus, the top three pore-water samples (from cores) in Table 3-13 of the Draft EIS were from the same depth zone as the perched water and the fourth was from near its base. Striffler et al. (1996) also includes analysis of saturated zone waters from boreholes G-2 and H-1. However, Table 3-13 of the Draft EIS does not include these results. Yang, Rattray, and Yu (DIRS 100194-1996) present several chemical analyses of pore waters from below the perched zone in UZ-14. However, there is little variability among common ions (see DIRS 100194-Yang, Rattray, and Yu 1996).

7.5.3.2 (4543)
Comment - EIS001521 / 0056
Page 3-48, Saturated Zone, first paragraph--(Water Occurrence) Again, the upper confining unit description does not include the basal vitrophyre and nonwelded tuffs of the Topopah Spring Tuff (see page 3-45, Figure 3-15). Also, why change the names of the hydrologic units as they are listed for the Yucca Mountain vicinity on page 3-45, Figure 3-15, when discussing the hydrogeologic sequence immediately below the Mountain (middle volcanic aquifer on the figure is referred to as the lower volcanic aquifer in the text)? This causes confusion and is incorrect nomenclature when looking at the hydrogeology of the Yucca Mountain vicinity/area.

Response
DOE agrees with the first portion of this comment and, to be consistent, "the vitrophyre and nonwelded tuffs at the base of the Topopah Spring Tuff" has been added to the description of the upper volcanic confining unit.

With respect to the second part of the comment, a problem faced by the EIS in presenting a simplified picture of the groundwater hydrology at Yucca Mountain is that the multiple studies involved and referenced have not been totally consistent in their nomenclature. As a result, the text in the referenced paragraph of the EIS attempts to use a simple terminology that is frequently used and recognizes that the terminology is slightly different in some studies.

The confusion regarding nomenclature of hydrogeologic units in the saturated zone noted by the reviewer is regrettable and the result of changes triggered by varying U.S. Geological Survey reports. Luckey et al. (DIRS 100465-1996) presented a table correlating geologic thermomechanical and hydrogeologic units for the Yucca Mountain area (in which, incidentally, the lowermost part of the Topopah Spring Tuff is included in the Upper Volcanic Confining unit). D'Agnese et al. (DIRS 100131-1997) used different hydrogeologic units in describing the groundwater flow system of the Death Valley region. Then, in the *Yucca Mountain Site Description* (DIRS 137917-CRWMS M&O 2000), the U.S. Geological Survey introduced the nomenclature shown in Figure 3-15 of the Draft EIS, which used the new terms Middle Volcanic Aquifer and Middle Volcanic Confining Unit, and redesignated the Lower Volcanic Aquifer and Lower Volcanic Confining Unit to apply to older materials.

7.5.3.2 (4544)
Comment - EIS001521 / 0057
Page 3-48, Saturated Zone, second paragraph--"Downstream" is a surface-water term, and is not used for discussing ground-water movement. Down gradient is appropriate. Also, there are many flowpaths beneath Yucca Mountain,

not one, as the discussion seems to indicate. Relate the first sentence of this paragraph to page 3-38, Figure 3-13, for clarity.

Response
DOE agrees that downgradient is more accurate, and the Final EIS now uses it, rather than downstream. In addition, DOE agrees that the description of the flowpath in this paragraph is a simplification. However, the attempt here is to describe how the transition is made from the volcanic aquifers being the primary source of groundwater at Yucca Mountain to the valley-fill aquifer being the primary source of groundwater in Amargosa Desert. DOE believes that the paragraph accomplishes this without being overly complex for the average reader. The wording regarding the groundwater flow path is consistent with the *Total System Performance Assessment – Viability Assessment* (DIRS 101779-DOE 1998). DOE has added a figure to Section 3.1.4.2.2 that depicts a generalized hydrogeologic cross section of the area that helps clarify this discussion.

7.5.3.2 (4545)
Comment - EIS001521 / 0058
Page 3-48, Saturated Zone, third paragraph--"Evidence" for water ages should be given, or at least an example, with statements and values referenced. In fact, nearly every sentence in this paragraph (continued at the top of page 3-49) requires a reference. "Limited data" do not show anything unless they are shown. And referenced.

Response
Evidence for the age of the water is contained in Sections 5.3 and 9.2 of the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Table 8.2-9). In response to this and other comments, DOE has added specific citations to Section 3.1.4.

7.5.3.2 (4546)
Comment - EIS001521 / 0059
Page 3-49, first paragraph--(top of page) The statement, "This indicates that, in the vicinity of Yucca Mountain, water from the lower carbonate aquifer is pushing up against a confining layer with more force than the water in the upper aquifers is pushing down" which defines the relationship of confining pressure, hydrostatic pressure, and related overburden "weight" is totally misleading. Recharge areas were not mentioned (altitude relationships), and many confined aquifers are not overlain by other aquifers but by very thick sequences of confining materials that contain little or no extractable ground water. I suggest using a referenced definition from a book on hydrogeology to define the pressure relationships between confined versus non-confined aquifers.

Response
DOE does not believe that the EIS is misleading. The intent of the cited description is to present in simple terms the conditions observed in the vicinity of Yucca Mountain. DOE did not attempt to describe the reasons (higher recharge areas, overburden weight, etc.) behind the artesian condition, only that the condition was present. The comment is correct that many confined aquifers are not overlain by other aquifers, but at Yucca Mountain the volcanic aquifers do overlie the confined lower carbonate aquifer. DOE believes the EIS description appropriately states that water in the lower carbonate aquifer is at higher pressure than water at the bottom of the volcanic aquifer, and that the direction of leakage through the confining unit, if any, would be upward. Luckey et al. (DIRS 100465-1996) contains a more detailed discussion of this topic.

7.5.3.2 (4547)
Comment - EIS001521 / 0060
Page 3-49, second paragraph--During wetter periods, I doubt that the "saturated zone" was as much as 100 meters higher than it is today because the climatic conditions have nothing to do with tectonism; perhaps a clarification, that the water-table altitude (or another referenced aquifer water level) may be 100 meters higher today than during wetter periods, is needed.

Response
DOE has revised the subject paragraph to provide the clarification.

7.5.3.2 (4548)
Comment - EIS001521 / 0061
Page 3-50, second paragraph--(Hydrologic Properties of Rock) Define hydraulic conductivity, as other parameters are defined.

Response
DOE agrees with this comment and has defined "hydraulic conductivity."

7.5.3.2 (4549)
Comment - EIS001521 / 0062
Page 3-51, Table 3-14--Transmissivity (T) and hydraulic conductivity (K) numbers are not comparable, and of little use, since T values are given in units per day and K values are in units per year. Why make it so difficult to spot check the calculated T values by constantly requiring chronological versions of the K values? Also, more detail is needed about the calculated T values as shown in the table. On quick inspection, using the given unit thickness (or thickness range) and the given K-value range, the T-value range for the upper volcanic aquifer is 38.6 to 5,671 square meters per day (not 120 to 1,600); for the upper volcanic confining unit the range is 1.8 to 85.9 (not 2.0 to 26); for the lower volcanic aquifer it is <1.4 to 9,014 (not 1.1 to 3,200); and the T-value range for the lower volcanic confining unit is 0.002 to >82.6 square feet per day (not 0.003 to 23). Of course, these values need to be "rounded" using significant-figure protocol. The higher end members of the estimated T-value ranges would have a significant impact on the potential movement of contaminants through this hydrogeologic system, so the T values in Table 3-14 need to be substantiated.

Response
The apparent hydraulic conductivity values have been changed to values in meters per day from values in meters per year for ease of comparison with transmissivity values presented for those units in Table 3-14 of the Draft EIS. The transmissivity (T) and "apparent" hydraulic conductivity (K) values are all from Luckey et al. (DIRS 100465-1996). As explained in that reference, the hydraulic conductivity values were calculated by dividing the reported transmissivity of the tested interval by the thickness of that interval in the borehole, which Luckey et al. (DIRS 100465-1996) recognized might be misleading and therefore used the term "apparent hydraulic conductivity" in the table. Because Table 3-14 of the Draft EIS lists "typical thickness" of the hydrogeologic units (also derived from DIRS 100465-Luckey et al. 1996), it is not surprising that the back calculation of T values from "apparent" hydraulic conductivity and "typical" thickness as described in the comment does not agree with tabulated T values. The text introducing Table 3-14 points out some of the problems in applying single borehole test data to hydrogeologic units, but the more detailed discussions in Luckey et al. (DIRS 100465-1996) are especially pertinent to this comment.

7.5.3.2 (4550)
Comment - EIS001521 / 0064
Page 3-53, first paragraph--Reference age-date values and climatic discussion.

Response
Section 3.1.4 of the Final EIS now references the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000), and specific citations have been added to the text. Age-dating information and discussion of climates is from CRWMS M&O (DIRS 151945-2000).

7.5.3.2 (4551)
Comment - EIS001521 / 0065
Page 3-53, second paragraph--Again, Fortymile Canyon or Wash? Also, define "substantial" recharge. The connotation is that 3,400 acre-feet of recharge along the course of Fortymile Canyon are "not" substantial, true or not? To most hydrogeologists this amount of recharge, in an arid environment, is indeed substantial.

Response
"Fortymile Wash" is the intended terminology in this case. The Fortymile Wash recharge discussion in the EIS has been revised to reflect the results of a more recent study. As described in the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000), the more recent study (DIRS 102213-Savard 1998) incorporated a loss factor not considered in the previously cited study (DIRS 100602-Osterkamp, Lane, and Savard 1994) and, accordingly, is

believed to result in a more appropriate estimate of infiltration actually reaching groundwater. The newer estimates of recharge through Fortymile Wash are notably decreased from those presented in the Draft EIS. The EIS now presents a recharge estimate for only a 42-kilometer (26-mile) section of the wash that is in the area of Yucca Mountain as compared to the entire 150-kilometer (93-mile) length described in the Draft EIS. This further reduces the average annual recharge value now identified in the EIS as 110,000 cubic meters (88 acre-feet).

7.5.3.2 (4552)
Comment - EIS001521 / 0066
Page 3-53, sixth paragraph--(Outflow from Volcanic Aquifers at and Near Yucca Mountain) Again, a potentiometric-surface map would greatly clarify the discussion of the configuration of the ground-water surface. A lot is left to "faith" in these discussions (are descriptions accurate?). Also, again, page 3-38, Figure 3-13, does not show ground-water movement to and discharge occurring in Death Valley; it is questioned.

Response
DOE has added a figure to Chapter 3 of the Final EIS to show the estimated potentiometric surface of the Death Valley region. As noted in the legend to Figure 3-15 in the Draft EIS, the question mark on the figure indicated uncertainty concerning a component of the groundwater flow path from the Amargosa Desert to the Furnace Creek area. To avoid confusion, DOE has removed the question mark and the legend note from the figure.

The natural discharge point for groundwater from beneath Yucca Mountain is Franklin Lake Playa. A small amount of groundwater might flow through fractures in the relatively impermeable rocks in the Funeral Mountains toward discharge points in Death Valley.

7.5.3.2 (4553)
Comment - EIS001521 / 0067
Page 3-55, Figure 3-17--Are the legend designations rock types or aquifers (for example, carbonate rock)? If they are rock types, hydrologic and water-quality information collected from relevant wells are not correlative, and thus useless.

Response
The legend indicates the aquifer from which DOE has drawn water samples. DOE has changed the legend from "contributing unit" to "contributing unit (aquifer)."

7.5.3.2 (4554)
Comment - EIS001521 / 0068
Page 3-56, Table 3-16--This is a very difficult table to analyze. What is a median water level? Water levels are usually established as an annual average or more often, measurements are made on given dates and are compared on a year-to-year basis. What was the period of measurement for the study? Was it 1992 through 1997? Is "Average deviation about the median" an annual average fluctuation or a fluctuation from year-to-year on a given date? Also, for "Difference (from the) baseline," are median and baseline equal terms? Water levels measured in production wells (J-12 and J-13) are meaningless.

Response
Table 3-17 summarizes water-level changes in seven wells in Jackass Flats that have been monitored for several years. Results of the monitoring have been published by the USGS in annual reports, the latest of which, is cited as the source of Table 3-17. Explanations of the monitoring program and the data presentation given in the cited source answer the questions raised by the commenter.

Regarding median water levels, "median" is used in the usual statistical sense of the mid-point value of a ranking of several values, such as an annual median water level. As explained in La Camera, Locke, and Munson (DIRS 103283-1999), the median water level is used because the calculated median is less affected by a few high or low values than the arithmetic mean.

Regarding the period of record, as shown in hydrographs for all seven wells, the period of record ranges from 1983 to the present for most wells, although the record for well J-11 began in 1990, and for well JF-3 in 1992.

"Average deviation about the median" is explained in the text and graphically in La Camera, Locke, and Munson (DIRS 103283-1999). For each well, an average median water level was calculated for a baseline period, depending upon the available records. This baseline period was 1985-91 for JF-1, JF-2, and JF-2a; 1989-91 for J-13; 1990-91 for J-11 and J-12; and 1992-93 for JF-3. This baseline median (column 2 in Table 3-17) then serves as a standard for comparison for each well. For each well, a median water level is calculated and the yearly difference of this value from the baseline median is shown in columns 4 through 9 of Table 3-17. Thus, a consistent downward water-level trend is represented by a series of negative values in columns 4-9, as in the case of wells J-12, J-13, and JF-3. Conversely, a rising trend is indicated by a series of positive values, as in the case of J-11 and JF-2a. The U.S. Geological Survey has used this particular style of data presentation for many years in annual reports on groundwater data for the Yucca Mountain Region.

With regard to the observation that water level in production wells J-12 and J-13 are meaningless, DOE assumed that the comment indicates a belief that these represent pumping levels. This is not the case. As explained in La Camera, Locke and Munson (DIRS 103283-1999), water levels in wells J-12, J-13, and nearby JF-3 that might have been affected by pumping or recent pumping of the wells are not in the database.

DOE does not believe that further explanation is needed for Table 3-17 in the EIS because most of the questions relate to standard data presentation by the U.S. Geological Survey, which is explained in the reference cited as the source of the data.

7.5.3.2 (4556)
Comment - EIS001521 / 0069
Page 3-57, first paragraph --The nearness to or distance from Fortymile Canyon (or Wash) has little, if anything, to do with water levels measured in the wells. The key is, in which aquifer is each well completed? According to page 3-56, Table 3-16, the two wells with largest positive variations in water level were JF-2a and J-11. Well JF-2a is completed in carbonate-rock (aquifer) and well J-11 is completed in volcanic-rock (aquifer)(see page 3-55, Figure 3-17), the latter being located some six miles east of the other five wells completed in a north-south line near Fortymile Canyon (which are also completed in volcanic rock). Well JF-2a water levels are obviously not connected to like measurements made in the Fortymile Canyon well array. Well J-11 is located down-dip geologically (see page 3-43, Figure 3-14, for the general geological attitude of units) from the north-south Fortymile Canyon well array, and is probably completed in a differing volcanic aquifer than wells JF-1, JF-2, JF-13, JF-12, and JF-3. Well-completion data, constructed hydrogeologic cross-sections, and water-quality data would help resolve this issue and more clearly define the hydrogeologic system.

Response
The comment is correct that distance from Fortymile Wash has little bearing on water level changes in wells JF-2a (UE 25 p#1) or J-11. DOE has revised the paragraph referred to in the comment, noting that well JF-2a taps the lower carbonate aquifer and, therefore, pumping from the volcanic aquifers would be unlikely to affect that well, and that well J-11 is a long distance from and up the hydraulic gradient from active production wells J-12 and J-13.

7.5.3.2 (4557)
Comment - EIS001521 / 0070
Page 3-57, Table 3-17--Composite water-quality data are presented for 12 volcanic-aquifer wells (footnote b), but page 3-55, Figure 3-17, shows only eight (by my count) wells completed in volcanic rock. Why the discrepancy? Also, are all 12 of these volcanic-aquifer wells completed in the same aquifer? Is there a water-quality variation from the upper-volcanic aquifer to the lower-volcanic aquifer? Correlate tabular water-quality data with well-completion data and show an appropriate location map.

Response
Figure 3-17 is not related to Table 3-18. The figure is a map of sites in the Yucca Mountain region where water-level measurements are made, whereas Table 3-18 presents data on water chemistry from aquifers at Yucca Mountain. Table 3-18 now cites Benson and McKinley (DIRS 101036-1985) as the source of the analyses and the wells sampled that are identified in that table.

Fourteen wells were sampled to generate the volcanic-aquifer data presented in Table 3-18. Footnote b has been changed accordingly. (The original count considered the C-well complex as one well rather than three separate wells.)

The intent of Table 3-18 of the Draft EIS is to show a general difference between water from the volcanic aquifers and water from the carbonate aquifer. The DOE believes this is achieved in the table without providing more complicated detail. Although lateral differences in chemical quality of water in the volcanic aquifers at Yucca Mountain are observed, other than the pronounced difference from water in the carbonate aquifer noted in the EIS, little difference in chemical or isotopic character has been noted relating to stratigraphy of the volcanic rocks.

7.5.3.2 (4558)
Comment - EIS001521 / 0071
Page 3-58, Table 3-18--Separate the two volcanic aquifers (upper and lower) in the "Contributing aquifer" column, if possible. Also, footnote b reference to Figure 3-18 should be to Figure 3-17.

Response
The source document for the data listed in Table 3-18 of the Draft EIS does not distinguish or identify the aquifer that the "volcanic" wells tap, only that they are intended to be representative of water from the volcanic sequence. Separating the volcanic aquifers in the table would not be practicable, because well J-13 taps the upper volcanic aquifer, the upper volcanic confining unit, the lower volcanic aquifer, and the lower volcanic confining unit, whereas the C wells tap the upper volcanic confining unit and the lower volcanic aquifer (see DIRS 100465-Luckey et al. 1996).

DOE has changed footnote b to refer to what was Figure 3-17 in the Draft EIS.

7.5.3.2 (4559)
Comment - EIS001521 / 0072
Page 3-58, first paragraph--(sentence immediately following Table 3-18). Will monitoring for comparisons between the differing contributing aquifers continue throughout the operation of the proposed repository and well into the post-closure period? It would be reassuring, if true.

Response
DOE has supported Nye County with it's program (called the *Early Warning Drilling Program*) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain, as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the performance confirmation program (if Yucca Mountain is approved for a repository), could be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information was available from the Early Warning Drilling Program. Since then this program has gathered more information (see Section 3.1.4.2.1 of the EIS).

Monitoring requirements directly associated with proposed repository operations could be specified in a Nuclear Regulatory Commission license. DOE would develop this monitoring program based on data collected from the performance confirmation program, the Early Warning Drilling Program, and future regulatory requirements. The purpose of the performance confirmation program would be to determine if the repository was performing as predicted.

DOE would design and implement a postclosure monitoring program in compliance with the Nuclear Regulatory Commission regulations (10 CFR Part 63). Before closure, DOE would submit an application for a license amendment to the Commission for review and approval. The application would include, among other items:

1. An update of the assessment of the performance of the repository for the period after closure

2. A description of the postclosure monitoring program

3. A detailed description of measures to regulate or prevent activities that could impair the long-term isolation of the waste, and to preserve relevant information for use by future generations

The application also would describe the DOE proposal for continued oversight to prevent any activity at the site that would pose an unreasonable risk of breaching the repository's engineered barriers, or increase the exposure of individual members of the public to radiation beyond limits allowed by the Nuclear Regulatory Commission. DOE has modified Chapter 9 of the EIS to include the types of monitoring and other institutional controls that would be contemplated. The Department would develop the details of this program during the consideration of the license amendment for closure. This would allow DOE to take advantage of new technological information, as appropriate.

7.5.3.2 (4566)
Comment - EIS001521 / 0080
Page 5-24, Figure 5-3--The flow-direction arrow in the lower southeast corner of the figure (near and pointing towards the California-Nevada border) is not within the Central Death Valley (hydrologic) Subregion, as shown on page 3-38, Figure 3-13. Why is it shown and is it important? Also, again, the community of Lathrop Wells is now known as Amargosa Valley.

Response
This comment is correct. Figure 5-3 no longer shows the flow arrow. In addition, DOE has changed "Lathrop Wells" to "Amargosa Valley" in the figure and text in Section 5.3.

7.5.3.2 (4583)
Comment - EIS001521 / 0095
Also during the discussion of geology, hydrogeology, and hydrology in Chapter 3 there is great confusion from one section to another when trying to determine the differences between (or similarities among) designations for, physical and chemical characteristics of, structural controls on, and areal and sub-surface extents of discussed units.

Response
The subject comment is not sufficiently specific for a direct response. However, it should be noted that all comments received are considered in revisions to the EIS, and insofar as feasible, confusion between sections will be eliminated.

7.5.3.2 (4763)
Comment - 010447 / 0002
Scientists from Lawrence Livermore and Los Alamos National Laboratories have reported that plutonium from an underground nuclear weapons test at Pahute Mesa on the Nevada Test Site had migrated almost a mile from the where the test had occurred. This finding contradicts DOE predictions about how fast plutonium moves through groundwater pathways. Until now, DOE had contended that plutonium movement is slow, several inches or feet over hundreds of years. This major discovery that plutonium has moved almost a mile in less than 30 years has great implications for DOE's plans to isolate spent nuclear fuel and high-level radioactive waste at Yucca Mountain.

Response
Section 3.1.4.2.2 of the EIS describes recent findings on the Nevada Test Site concerning the migration of plutonium. The small amount of plutonium detected in groundwater farther than expected from its source (a 1968 underground nuclear test) was apparently associated with the movement of colloids (very small particles). These findings suggest that radionuclides that are attached to colloids move faster than dissolved radionuclides because the colloids can travel in the faster parts of the flow paths, and sorb less onto host rocks than do dissolved radionuclides. Thus, the potential for faster movement of colloids becomes particularly important for radionuclides with high sorbtion, such as plutonium. Analysis of the long-term performance of the proposed repository incorporates the potential for plutonium to move with colloids (see Chapter 5 and Appendix I of the EIS). As described in Section I.3.1, DOE left plutonium species (specifically plutonium-239 and -242) in the model in spite of high sorbtion rates because of the large inventory that would be in the repository and the potential for colloidal transport. Consistent with this, the summary of modeling results in Section 5.4.2 attributes projected impacts from plutonium migration to colloidal transport, not transport as a dissolved element. The modeling of plutonium transport on colloids began with parameters derived from data obtained on the Nevada Test Site. The modeling, however, included input

parameters that were above and below those derived from the Test Site data because the specifics of colloid properties and transport are not well known.

7.5.3.2 (4778)
Comment - EIS001519 / 0004
Statements about the unlikelihood of nuclear waste contaminating groundwater because of the dry, dusty climate in the Yucca Mountain are incorrect when the effects of a climate change are taken into consideration. Since the 1970s the global temperature has continued to increase, and the 1990s has been the hottest decade ever. Should this increase continue, the possibility of polar ice melting also increases, which would raise the water level, possibly into the level of the repository where contamination would occur. In addition, a sudden, rapid climate change even within the next ten years could raise the water table within dangerous proximity of the repository.

Response
Several phenomena affect the energy budget of the atmosphere on short time scales, ranging from decades to centuries. These events include perturbations such as solar variability, volcanism, variation in carbon-dioxide content, and the El Niño southern oscillation. Human-caused increases in carbon dioxide have generated much scientific and public concern, because higher levels of atmospheric carbon dioxide trap outbound long-wave radiation, thus warming the Earth.

The consequences of a warmer Earth would almost certainly result in greater amounts of water vapor entering the atmosphere, which would increase precipitation in some areas. However, it is not known if climate changes affect carbon dioxide levels or vice versa. The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) describes the timing, magnitude, and character of past climate changes in the Yucca Mountain area and establishes the rationale for projecting such changes into the future. Based on this information, a model of climate change has been developed in which the modern-day climate at Yucca Mountain would persist for another 400 to 600 years, followed by a warmer and much wetter monsoon climate for 900 to 1,400 years, followed by a cooler and wetter glacial-transition climate for 8,000 to 8,700 years.

Inundation of the repository by rising groundwater during any of these climate changes would be highly improbable because no credible mechanism can account for such a rise. Szymanski (DIRS 106963-1989) proposed that during the last 10,000 to 1 million years, earthquakes and volcanic activities drove hot mineralized groundwater to the surface at Yucca Mountain and deposited calcite and opal. This hypothesis goes on to suggest that similar forces could raise regional groundwater in the future and inundate the repository horizon.

DOE requested the National Academy of Sciences to conduct an independent evaluation. The Academy concluded in its 1992 report (DIRS 105162-National Research Council 1992) that no known mechanism could cause a future inundation of the repository horizon. The geologic evidence indicates that groundwater never reached the repository horizon; in fact, the largest rise might have been about 115 to 120 meters (380 to 390 feet) during the last several million years. Earthquakes could raise the water table by at most 20 meters (66 feet). The 1992 Little Skull Mountain earthquake raised water levels in some monitoring wells by a maximum of less than 1 meter (3 feet).

Dublyansky (DIRS 104875-1998) proposed another line of data in support of the warm water upwelling hypothesis. That study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. It concluded that some crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of independent experts, including scientists from the U.S. Geological Survey, did not concur with Dublyansky's conclusions. DOE disagrees with the central conclusions in this report, but has supported continuing research by the University of Nevada, Las Vegas. See Section 3.1.4.2.2 of the EIS for information on groundwater at Yucca Mountain.

7.5.3.2 (5161)
Comment - EIS001444 / 0014
Water Resources
There is no specific reference to any model that was used, other than modeling was done for the unsaturated zone or a 3-D model was developed for the saturated zone. What are the names of the models used?

Response
Appendix I of the Draft EIS contains details on the models used. In particular, Figure I-1 shows the interrelations of models used in the total system performance assessment. The regional model was developed by the U.S. Geological Survey and was built using the MODFLOWP computer program.

7.5.3.2 (5199)
Comment - EIS001443 / 0024
The DEIS recognizes uncertainties about groundwater flow boundaries among sub-basins within the Death Valley groundwater basin. Contamination of the deep regional aquifer which appears to underlie both Yucca Mountain and the Tecopa-Shoshone-Death Valley Junction area, poses the most significant long-term threat to the citizens and economy of Inyo County. Inyo County, in conjunction with Nye and Esmeralda Counties (Nevada) and the USGS, have engaged in groundwater research which points to a direct connection between water in the deep 'Lower Carbonate Aquifer' beneath Yucca Mountain and surface discharges (springs) in Death Valley National Park ("An Evaluation of the Hydrology at Yucca Mountain: The Lower Carbonate Aquifer and Amargosa River," Inyo & Esmeralda Counties, 1996, and "Death Valley Springs Geochemical Investigation," Inyo County, 1998, provided as Attachments A & B). These studies were funded with DOE grant money and done to a high standard of scientific accuracy, being subject to Federal (USGS) quality assurance and quality control measures.

The 1996 study of the Lower Carbonate Aquifer suggests a significant degree of hydrologic connectivity between the Lower Carbonate Aquifer lying beneath the proposed repository and surface manifestations of the same formation within Death Valley National Park. The study also indicated that populations in Amargosa Valley (including the California towns of Death Valley Junction, Shoshone, and Tecopa) utilize groundwater that may be hydrologically contiguous to a southward extension of the Lower Carbonate Aquifer.

The 1998 investigation of the geochemistry of spring waters in the mountains east of Death Valley (some of which are developed to serve domestic and commercial uses in Death Valley) gave indications that these spring waters may be dominated by input from the Lower Carbonate Aquifer, perhaps via relatively fast pathways through fractures in the formation. It should be noted that these same springs also sustain populations of a number of threatened and endangered species.

The Draft Environmental Impact Statement does not address our findings, either to acknowledge or deny the implications of these studies with regard to potential pathways for contaminants to reach human populations or a National Park. Our studies, which have been available to DOE for some time, are absent from the estimated 50,000 pages of technical background material which went into development of the DEIS. We are formally including, by reference, these studies into our comments on the DEIS.

The County considers this a critical oversight on the part of DOE, which should be rectified by serious consideration of our scientific work and placement of our findings in the proper context.

The entire range of available scientific studies on groundwater flow in the Amargosa Valley, including applicable groundwater dating methodologies and flow velocity measurements, should be discussed. Competing models and methods and their results should be compared by the DEIS to provide a clear view of the current state of knowledge on the region's hydrology. The discussion of subsurface transport mechanisms of radionuclides needs further development, comparing the potential roles of colloidal, suspended particulate, and solution transport of contaminants under a range of assumptions about climate and subsurface conditions.

Specific Recommendation: DOE should review the above-cited research products for merit, incorporating the information into the hydrology database compiled for purposes of evaluating potential impacts to regional aquifers. If our reports have been submitted using a format or methodology not acceptable to DOE, Inyo County should be informed immediately to allow the County to redirect our research and reporting efforts. The DEIS should utilize the entire range of available hydrologic models and methods to bound projections of groundwater flow, contaminant transport concentrations, and velocity in the region potentially impacted by release of radioactive contaminants from the repository.

Response

Section 3.1.4.2.1 of the EIS acknowledges that the groundwater flow path from Yucca Mountain extends to Jackass Flats, the Amargosa Desert, and then southward to the primary point of discharge at Franklin Lake Playa in Alkali Flat southeast of Death Valley Junction. Some of the groundwater that reaches Franklin Lake Playa might bypass the playa and continue on to Death Valley via Tecopa and Shoshone. The EIS also acknowledges that a fraction of the groundwater beneath the Amargosa Desert might flow through the southeastern end of the Funeral Mountains toward springs in the Furnace Creek Wash area of Death Valley.

Chapter 5 of the EIS does not specifically address risks to people and natural resources in the areas of Tecopa, Shoshone, or Death Valley National Park from groundwater use and consumption. However, it can be clearly seen in the evaluations in Chapter 5 that risks would decrease with increasing distance from the repository. Accordingly, impacts to these other areas, because they are farther away on the groundwater flow path, would be less than those for the furthest distance evaluated in the EIS. Section 5.9 of the EIS addresses impacts to biological resources as a result of the long-term performance of the repository. As indicated in this section, DOE does not quantify impacts to biological resources from exposures to contaminated groundwater. Rather, DOE equates impacts to biological resources to the negligible impacts expected to humans from the use and consumption of this groundwater.

Regarding the comment's discussion of the referenced geochemistry report, the conclusion stated in the comment is not consistent with the conclusion of the report. The comment states that the investigation documented in the report "… gave indications that these spring waters may be dominated by input from the Lower Carbonate Aquifer." However, in describing the source of the Death Valley springs, the report's conclusion states that it remains unanswered. The report further concludes, "The water can come from recharge in 1) the area of the NTS [Nevada Test Site] and Yucca Mountain; or 2) the Amargosa Basin fill deposits, or 3) the area to the east that includes the Ash Meadows springs, or some combination of all three" (DIRS 147808-King and Bredehoeft 1999).

DOE acknowledges receipt of the two reports identified by the comment. These reports are not specifically referenced in the EIS (similar to numerous other source materials that are not specifically referenced), because their conclusions are not contradictory or inconsistent with the information already in the EIS. With respect to the conclusion discussed in the preceding paragraph, for example, the EIS identifies the possible link between groundwater beneath the Amargosa Desert and the springs in the Furnace Creek area, and suggested that some of this spring discharge could involve groundwater from beneath Yucca Mountain. The second report cited by the comment ("Lower Carbonate Aquifer") concludes that: (1) groundwater movement beneath Yucca Mountain is upward out of the carbonates into the tuff; (2) if contaminants reach the carbonates, travel times could be relatively short; (3) discharges to springs on the east side of Death Valley appear to be linked to the carbonates; (4) Esmeralda County is not in the groundwater flow path from Yucca Mountain; and (5) there are geohydrologic data gaps with respect to the carbonate aquifer (DIRS 147808-Bredehoeft, King, and Tangborn 1996). DOE believes that these conclusions are consistent with information in the EIS.

Chapter 5 of the EIS describes how the movement of contaminants, released from the slow degradation of the waste packages within the repository, has been modeled. The model factored in the slow movement of water through the rock matrix and the relatively fast movement of water along rock fractures and faults. Although the rate at which groundwater moves is very important to the model, it is not the only factor that controls the movement of contaminants. Section I.2.4 of the EIS describes how the waste package degradation has been modeled and how the cladding and waste form degradation models come into play before the contaminants would become available for transport through the unsaturated and saturated zones. Section I.2.4 also describes the various mechanisms that would affect how these materials move through these zones, including movement with colloids and the sorption and desorption that would take place as individual radionuclide or chemical species interacted with the rock through which they were moving. These and other parameters have been integrated into the performance assessment model to present a defendable and conservative estimate of impacts to groundwater and downgradient users of that groundwater.

The site characterization program at Yucca Mountain has gained valuable knowledge about the groundwater flow system, but it is recognized that collecting additional data would reduce several uncertainties regarding the long-term performance of the repository. It is recognized, however, that some uncertainty is inherent to the process. The approach taken in the long-term performance assessment was to recognize the uncertainties that are important to the evaluation, and then identify which uncertainties could be reduced by additional data and which ones would not.

With respect to uncertainties due to data gaps, the approach is to use conservative assumptions where necessary, with the understanding that the information gained from ongoing studies may eventually support less conservative assumptions and less conservative estimates of impact. These and other types of uncertainties are discussed further in Section 5.2.4 of the EIS. Section 5.2.4 also addresses issues of variability (as opposed to uncertainties) associated with the natural features of the system being modeled. It then goes on to describe the various techniques, such as sensitivity analysis, used in the modeling effort to analyze uncertainties and variabilities and to gauge their affects on the modeling results.

In summary, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3.2 (5270)
Comment - EIS001887 / 0024
The Draft Environmental Impact Statement (Draft EIS) for the Yucca Mountain high-level waste project includes an evaluation of environmental consequences (in terms of dose) of alternative repository design concepts and alternatives. The conclusion drawn from the results of these evaluations is that compliance is achieved.

There is, however, strong evidence that casts doubt on the validity of the conclusions and these compliance assessments in light of NWPA and NEPA [National Environmental Policy Act] requirements. This evidence is related to the choice of groundwater pathways selected for the analyses.

At Yucca Mountain, the primary human exposure pathway is through ingestion of groundwater. In conducting a performance assessment for Yucca Mountain, an accurate view of the groundwater flow field is essential. The velocity of the groundwater is one of the most sensitive parameters in the transport equation and, therefore, strongly influences dose calculations. The direction of the groundwater pathway is important as it dictates the hydrologic and geochemical character of the rock encountered along the pathway. Direction, along with velocity, strongly influences sorption and other important variables such as dilution and effective porosity in the saturated zone.

There has been considerable debate over the actual flow paths that would be followed by radionuclides released from the repository. Modeling results performed by the State of Nevada (Lehman and Brown, 1994, Lehman and Brown, 1995) indicate major differences may exist in flow path direction, velocity, and sorptive capability compared to that used in the latest assessments by DOE, including the Draft EIS, if all available data sets are utilized.

By failing to evaluate credible alternative models or opposing views of the saturated zone, DOE is not in compliance with NEPA. Being out of compliance with NEPA means automatic noncompliance with the NWPA. DOE is specifically out of compliance with NEPA Section 1502 for not summarizing, discussing or using important data sets; failure to evaluate credible opposing viewpoints; and not proposing testing to reduce uncertainty in the choice between alternative conceptual flow paths.

Response

DOE believes that the evaluation of potential environmental consequences documented in the EIS does present a sound case for compliance. This comment mentions that the choice of groundwater pathways selected for the analysis of compliance in the EIS is flawed due to the omission of unspecified data sets. Without identification of these data sets it is not possible to address this issue specifically. Therefore, the following discussion addresses pathway selection from the standpoint of an overall assessment of the present state of knowledge of saturated zone flow in the vicinity of Yucca Mountain.

The comment makes several references to the modeling performed by Lehman and Brown, particularly the evaluation of alternative saturated zone flowpaths that their work suggests. DOE scientists performed an assessment of their modeling efforts and concluded that, due to weaknesses in the model and the results of more recent hydrologic and chemical investigations, there is insufficient support for the suggested alternative flowpaths. Specific model deficiencies include model documentation, lack of data supporting wide, permeable northwest-oriented fault zones, poor agreement to observed temperatures (Solitario Canyon and Paintbrush faults), permeabilities much larger than documented in some areas, and over-constrained boundary conditions (DIRS 151948-CRWMS M&O 2000).

Key features of the saturated zone conceptual model suggested by Lehman and Brown (DIRS 149173-1996) require water movement across the repository block from west to east via discrete northwest-trending fracture zones. The proposed model suggests that another fault zone exists just to the south of the repository footprint. The following paragraphs contain specific examples of field data and hydrochemical investigations that contrast with the conclusions of the State's investigators.

Immediately to the west of Yucca Mountain the elevation of the water table increases abruptly approximately 45 meters (148 feet) as you cross the Solitario Canyon Fault going from east to west. This change in water table elevation is presumably due to a strong permeability contrast caused by juxtaposition of lithologic units and gouge along this fault. The net effect is to produce a geologic barrier that inhibits hydrologic communication across the fault. Evidence of this barrier is seen in the different chemical and isotopic signature of water collected from the east and west sides of the fault. A similar barrier to north-south flow may exist along Yucca Wash to the north of Yucca Mountain.

Additional evidence of the isolation of the flow regime near Yucca Mountain comes from analyses of uranium-234:uranium-238 ratios. Anomalously high ratio values initially established in the unsaturated zone are preserved in the upper saturated zone beneath Yucca Mountain, a condition which would not be expected if sufficient throughflow of water (moving either north to south, or west to east) was passing beneath Yucca Mountain. Reducing chemical conditions have been observed in the upper saturated zone near the site east of the fault (borehole WT-17), indicating a lack of dissolved oxygen and restricted circulation. This is in sharp contrast to values recorded in the channel of Fortymile Wash at the latitude of Yucca Mountain where moderate uranium-

234:uranium-238 ratios, oxidizing conditions, and younger water is observed. Simply put, the water that underlies Yucca Mountain appears to lie within a backwater that experiences limited throughflow and sluggish circulation. All of these findings argue against the high-permeability flow paths suggested by the Lehman and Brown (DIRS 149173-1996) model.

The comment states correctly that groundwater velocity is one of the most sensitive parameters in the transport equation. The preceding paragraph offers several lines of evidence that argue against rapid flow in the saturated zone beneath Yucca Mountain.

In addition, mapping recently conducted to refine the geologic model of Yucca Mountain did not find any evidence to support the State's contention regarding the existence of an undiscovered high-permeability fault zone south of the site. In conclusion, consideration of the available data from field studies and analytical laboratory determinations do not support the alternative model proposed by Lehman and Brown (DIRS 149173-1996).

7.5.3.2 (5496)
Comment - EIS001887 / 0164
Page 3-38; Section 3.1.4.2.1 - Regional Groundwater

Figure 3-13 should depict the entire Death Valley Regional Groundwater Flow System, not just a portion of the system, and include the associated groundwater flow paths. The Draft EIS states that the Death Valley Regional Groundwater Flow System is a closed system with groundwater not leaving the system except by evapotranspiration. Figure 3-13 should graphically show this.

Response
A figure has been added to show the entire Death Valley regional groundwater system and the subregion divisions.

7.5.3.2 (5498)
Comment - EIS001887 / 0166
Page 3-39; Section 3.1.4.2.1 - Regional Groundwater

Only the water quantity for the low thermal load is given here. What is the quantity for the intermediate and high thermal loads, and why were the data not given?

Response
In the Draft EIS, DOE used the water quantity for the low thermal-load because it represented the repository layout with the largest area, potentially intercepting the largest amount of infiltration from the surface, and therefore representing the most conservative estimate. Therefore, the water quantities for the intermediate and high thermal-loads were not provided. In Section 3.1.4.2.1 of the Final EIS, it is stated that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres) under one of the operating modes, assuming 4.7 millimeters (0.2 inch) of infiltration per year, would be about 0.2 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

7.5.3.2 (5503)
Comment - EIS001887 / 0167
Page 3-41; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

What would be "sufficient quantities of water" for DOE to collect? There are more than a few places in the ESF that dripped water.

Response
DOE has clarified this statement in Section 3.1.4.2.2 of the EIS. Researchers working in the Exploratory Studies Facility have encountered a few moist areas in the rock, but there no dripping water or water has accumulated or collected in the drift.

7.5.3.2 (5504)
Comment - EIS001887 / 0168
Page 3-42; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

Is perched water found only below the proposed repository horizon?

Why wasn't Chlorine 36 also used here, along with tritium?

Response
Within the proposed repository boundary, perched water bodies have been detected only below the waste-emplacement level. Hydrochemical analyses of samples from these perched water bodies show no detectable amounts of tritium and yield values of chlorine-36 only slightly above background levels. There is no evidence of recharge from recent infiltration of waters containing "bomb-pulse" isotopic indicators in any of the sampled perched water bodies.

The presence of perched water beneath the waste-emplacement level (above the regional water table) is a positive factor in relation to the potential transport of radionuclides for the following reasons:

1. The fact that the water is perched between the repository horizon and the water table indicates a barrier to flow. In this case, the perching layer possesses less matrix permeability and has a smaller fracture density than the overlying rocks

2. The age of the perched water is thousands of years. The perching layer appears to impede the downward flow of water so that the water has aged substantially (thousands of years) in its current location. This increased residence time provides greater potential for diffusion and sorption of radionuclides released from a breached repository.

7.5.3.2 (5506)
Comment - EIS001887 / 0170
Page 3-46; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

Define and quantify "relatively rapid water movement."

Response
Section 3.1.4.2.2 of the EIS indicates that water infiltration in the rock above the waste emplacement horizon slows substantially once it reaches the high porosity and low-density fracture zone of the Paintbrush nonwelded unit. Studies have shown residence times on the order of 10,000 years in the matrix of this unit (DIRS 104983-CRWMS M&O 1999). Also described in this section is the finding of "bomb-pulse" or "nuclear age" water at the waste-emplacement level. This finding indicates that some water has moved from the surface along isolated fracture pathways in the Paintbrush unit to the waste emplacement level within 50 years.

7.5.3.2 (5508)
Comment - EIS001887 / 0171
Page 3-46; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

Define and quantify "very small amounts" of fallout. What is the basis for the assumption of "very small amounts" of fallout?

Response
As indicated in the "Chlorine-36 Studies" text box in Section 3.1.4.2.2 of the EIS, chlorine-36 occurs naturally in the atmosphere. That is, it is part of the nonradioactive chlorine in the atmosphere that settles on the Earth's surface. Without a nuclear fallout contribution, the natural or background ratio of chlorine-36 to chlorine is about 500×10^{-15} (DIRS 151945-CRWMS M&O 2000). That is 1 part per 2 trillion (one chlorine-36 atom in 2 trillion chlorine atoms).

Global fallout from thermonuclear testing, primarily from tests in the Pacific Proving Ground, resulted in maximum meteoric chlorine-36-to-chlorine ratios of about 400 times background or $200,000 \times 10^{-15}$. Present day chlorine-36-to-chlorine ratios in surface soils at Yucca Mountain are generally in the range of $1,500 \times 10^{-15}$ to $3,000 \times 10^{-15}$ (DIRS 151945-CRWMS M&O 2000).

This is a simplification of the variables DOE considered in the chlorine-36 studies. However, it indicates the very small quantities of chlorine-36, with or without contributions from fallout that DOE is investigating. The Department did not intend the EIS text in question to be a statement on the importance of the fallout; but to indicate that the numbers are extremely small. The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) and *Evaluation of Flow and Transport Models of Yucca Mountain, Based on Chlorine-36 and Chloride Studies for FY98* (DIRS 104878-CRWMS M&O 1998) contain more information.

7.5.3.2 (5509)
Comment - EIS001887 / 0172
Page 3-47; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

Give the best estimate of groundwater travel time, not just less than 10,000 years.

Response
The analyses of groundwater travel times, which were reported in the Draft EIS, were originally prepared for the *Total System Performance Assessment -- Viability Assessment* (DIRS 101779-DOE 1998, Volume 3). These analyses used a conservative approach with respect to some aspects of the natural system; that is, the analyses incorporated parameter values that were meant to ensure that Total System Performance Assessment results would have little chance of being criticized as optimistic.

In general, the value of a conservative description of the natural system is to provide a more easily defensible Total System Performance Assessment for consideration by regulatory bodies. However, due to the compounding effects of such conservatisms, the model results presented in the Draft EIS are not suitable for evaluating groundwater travel time or examining the anticipated performance of the natural system because they present a somewhat unrealistic “worst case” scenario. Efforts are underway to produce a more realistic assessment of the performance of the natural system that is more suited to evaluation of anticipated transport and groundwater flow issues.

As part of its site characterization activities, DOE has undertaken various studies to identify and consider characteristics of the unsaturated (above water table) and saturated (water table) zones, such as the flow of water and transport of radionuclides, that are relevant to analyzing groundwater travel times. DOE also has considered physical evidence such as the chemistries and ages of water samples from these zones. Because of the inherent uncertainties in understanding such natural processes as groundwater flow, DOE has developed numerical models to represent an approximation of these processes and to bound the associated uncertainties.

Based on these models, which incorporate the results of these studies and available corroborating physical evidence, DOE estimates that the median groundwater travel times would be about 8,000 years (from the repository down through the unsaturated zone into the saturated zone and out to the accessible environment), and average groundwater travel times would be longer. These models indicate that small amounts of water potentially moving in “fast paths” from the repository to the accessible environment could do so in fewer than 1,000 years. However, the models and corroborating physical evidence indicate that most water would take much more than 1,000 years to reach the accessible environment. The long-term performance of the repository shows that the combination of natural and engineered barriers at the site would keep radionuclides well below the regulatory limits established at 40 CFR Part 197. See Sections 3.1.3, Section 3.1.4.2, and Section 5.4 of the EIS for additional information.

7.5.3.2 (5512)
Comment - EIS001887 / 0173
Page 3-49; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

The Draft EIS should discuss more fully the fluid inclusion work on the calcite and opal veins and coatings underway at UNLV. The Draft EIS contains a brief discussion of the controversy over evidence that hydrothermal activity may have occurred at Yucca Mountain in the past and could reoccur during the lifetime of the repository.

The text gives the misleading impression that this matter has been resolved in DOE's favor as a result of a NAS review of the issue. In fact, the issue is the subject of an ongoing joint study being implemented by the University of Nevada Las Vegas, DOE, and the State of Nevada. Preliminary indications from data and analysis emerging from this study indicate that fluid inclusions found in calcite-silica deposits at depth within the exploratory tunnel at Yucca Mountain are of hydrothermal origin. Work is ongoing to confirm this finding and to discover the age of the fluid inclusions. The outcome of this study has significant implications for the suitability of Yucca Mountain as a repository site and for the viability of the Proposed Action as described in the Draft EIS.

Response
Based on the results of the analyses in Section 3.1.4.2.2 of the EIS, DOE does not believe that a credible rise of the water table would inundate the waste emplacement areas. However, that section does discuss evidence that the elevation of the water table at Yucca Mountain has fluctuated over time, due largely to changes in the climate. In addition, DOE examined the cumulative effects on the elevation of the water table from a wetter climate, earthquakes, and a volcanic eruption. Based on the evidence at hand, no reasonable combination of wetter climates, earthquakes, and volcanic eruptions could raise the elevation of the water table sufficiently to inundate the waste emplacement areas at Yucca Mountain.

Section 3.1.4.2.2 of the EIS discusses several opposing views on fluctuations in the elevation of the water table at Yucca Mountain. These investigators believe that the water table has risen in the past to elevations that are higher than the proposed waste emplacement areas. DOE does not concur with these views, nor did an expert panel that the National Academy of Sciences convened to examine this issue (as described further in Section 3.1.4.2.2). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than 120 meters (390 feet) higher than the present level. Although DOE has disagreed with the central scientific conclusions in this report (DIRS 104875-Dublyansky 1998), it continues to support independent research in this area, as well as on other aspects of the geology and hydrology that enhances an understanding of the site. The Department considers the fluid inclusion study being conducted at the University of Nevada, Las Vegas, as a supplemental confirmatory research effort. The EIS includes an update on the status of the University's study.

7.5.3.2 (5514)
Comment - EIS001887 / 0175
Page 3-52; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

Provide the actual feet/mile or meters/kilometer for the slope of the water table east of the Solitario Canyon fault.

Response
DOE has added text to Section 3.1.4.2.2 of the EIS to quantify the gentle slope of the water table in this area.

7.5.3.2 (5515)
Comment - EIS001887 / 0176
Page 3-53; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

The use of the word "probably" in the third paragraph on this page does nothing but cause one to doubt the veracity of the statement.

Why is the average net infiltration rate on this page given as 4.5 millimeters over 220 square kilometers but on page 3-44, it is given as 4.5 millimeters over 230 square kilometers? Also, why wasn't the infiltration rate for the repository area used instead of the rate from the larger study area?

The statement that the groundwater pathway beneath Yucca Mountain is southerly conflicts with Figure 3-13 and other figures used in various DOE presentations that show an initial eastward flow of the groundwater, then down Fortymile Wash.

Response
DOE has deleted the word "probably" from the paragraph cited by the commenter. In the Draft EIS, the correct area is 220 square kilometers (89 square miles). It should be noted that estimates of net infiltration now presented in the

EIS are from a more recent infiltration study and differ slightly from those presented in the Draft EIS. Also, the analysis in question now uses the net infiltration rate estimated for the 4.7 square kilometer (1.8 square mile) repository area. The overall direction of groundwater flow in the basin is to the south and the initial eastward flow of the groundwater at Yucca Mountain is a local phenomenon, so DOE does not find a conflict between the statement and Figure 3-13 of the Draft EIS.

7.5.3.2 (5517)
Comment - EIS001887 / 0177
Page 3-54; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

Define and quantify the term "small" as used in the sentence regarding the volume of water pumped from USW VH-1.

Response
According to records supplied by the Yucca Mountain Project to the Nevada State Engineer, DOE has pumped less than 800 cubic meters (0.65 acre-foot) of water from borehole USW VH-1 since 1992. The Department considers this to be a comparatively small amount of water.

7.5.3.2 (5602)
Comment - EIS001887 / 0228
Page 4-25; Section 4.1.3.3 - Impacts to Groundwater from Construction, Operation and Monitoring, and Closure.

This section discusses the potential for contaminant migration to the groundwater and does not state whether any impacts to groundwater quality are predicted. It appears that DOE did not analyze potential water quality impacts of the repository project, especially consequences of long-term repository performance. The Draft EIS should indicate what analysis was used to determine impacts to water quality, if any, and show any impacts to water quality that might occur.

Response
As stated in Section 4.1.3.3 of the EIS, the depth to groundwater, the thickness of alluvium in the area, and the arid environment at Yucca Mountain would combine to reduce the potential for surface contaminants to reach groundwater during the preclosure period. Hence, DOE does not predict that contaminants from materials inadvertently released at the surface (or in the waste emplacement areas) would reach groundwater during the preclosure period. If such a release were to occur, however, DOE would remediate the site of the release according to procedures in applicable plans, such as a Spill Prevention Control and Countermeasure Plan.

Based on the results of extensive analyses reported in Chapter 5 of the EIS, DOE believes that a repository at Yucca Mountain would operate safely during the postclosure period. DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

7.5.3.2 (5603)
Comment - EIS001887 / 0229
Page 4-29; Section 4.1.3.3 - Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

What type of general groundwater flow patterns changes would be expected from pumping more than 0.72 million cubic meters from the western portion of Jackass Flats? Although the Draft EIS states that the changes would be "small," the changes expected and any impacts from these changes should be discussed here.

Response
Since issuance of the Draft EIS, two efforts have been completed to model groundwater flow and estimate impacts associated with water use for the repository and are described in Section 4.1.3.3 of the Final EIS. The results of one

effort, which assumed a conservatively high water demand for the repository over a period of 100 years, indicated a small [about 0.3 meter (1 foot)] drawdown from project pumping as far away as the community of Amargosa Valley after 100 years. It also indicated that the additional drawdown would be minor compared to drawdown from ongoing groundwater withdrawals in the region. The other effort compared two steady-state simulations (baseline and predictive future) and estimated a drawdown of less than 1.2 meters (4 feet) at Amargosa Valley as a result of the proposed action's water demand.

7.5.3.2 (5651)
Comment - EIS001887 / 0271
Page 5-11; Section 5.2.3.1 - Limited Water Contacting Waste Package

The last sentence of this section should state that the rate of water movement through the unsaturated zone can be from 50 years to thousands of year, not less than 100 years to thousands of years, as stated in this section.

Response
The commenter's suggested change would not alter the meaning of the sentence. DOE has therefore retained the original sentence in the Final EIS.

7.5.3.2 (5767)
Comment - 010027 / 0012
On Page 2-20 a number of repository layouts are illustrated. The "Flexible Design" and "Low Thermal Load" layout options extend further north than the proposed design. These, therefore, appear to extend closer to a location where, in previous analyses, the groundwater level would be closer to the repository horizon. This is not discussed or described, however, in the SEIS.

Response
Figure 2-7, on page 2-20 of the Supplement to the Draft EIS shows three repository layouts from the Draft EIS, with the fourth layout for the flexible design which is the current proposed design. This comment is correct in noting that the flexible design layout extends farther north than the layouts described in the Draft EIS. The comment is also correct that this is the area where the groundwater would be closest to the repository level. The Supplement does not go into detail on this change because it would be unlikely to make a notable change in the impacts of the Proposed Action.

The reported depth of groundwater from the level of the repository has been revised slightly in the Final EIS to account for new data and the small change in repository layout. As noted in Section 3.1.4.2.2, the repository block would be at least 160 meters (520 feet) and as much as 400 meters (1,300 feet) above the present water table. [The depth range described in the Draft EIS was 175 to 365 meters (570 to 1,200 feet).] These are conservative estimates of the depth from the repository to the water table taken from the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000). A more recent document, the *Yucca Mountain Science and Engineering Report* (DIRS 153849-DOE 2001), presents a similar repository layout figure for the flexible design, but it is superimposed with groundwater elevation contours. In Figure 1-13 of that report, and as described in the associated text, the depth from the primary block's northern most emplacement drift to the groundwater table would be about 210 meters (690 feet). The north main access drift loops a little farther to the north where groundwater would be higher, but it would not be a location of waste emplacement. Groundwater elevation contours that cover large areas, as shown in the figure in the Science and Engineering Report, must be based on a limited number of observation wells at which the depth to groundwater can be measured. As a result, there are uncertainties associated with the exact locations of contour lines between wells. However, in this case there is an observation well approximately 120 meters (390 feet) north of where the northernmost drift would lie. Accordingly, there is high confidence in the groundwater elevation contours in this immediate area.

7.5.3.2 (5809)
Comment - EIS001887 / 0441
The Nuclear Waste Policy Act requires that an EIS, consistent with the National Environmental Policy Act, be prepared and accompany a recommendation for site approval. The amended NWPA (1987) still requires consistency with NEPA, but does not require the DOE to consider:

1. The need for the repository
2. Alternative sites to Yucca Mountain, or
3. Non-geological alternatives

NWPA Section 114(f) specifically states that all other provisions of NEPA apply. NEPA Section 1502.22 relates to incomplete or unavailable information. NEPA regulations require that, if information is available that would aid in evaluating uncertain effects, it must be obtained and analyzed unless it is too expensive to do so. If costs are prohibitive, then it must be disclosed as incomplete or unavailable information. Specifically, regulations require that if information cannot be obtained, the EIS must include:

1. A statement that such information is incomplete or unavailable.

2. A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment.

3. A summary of existing credible scientific evidence that is relevant to evaluating reasonably foreseeable significant adverse impacts on the human environment.

4. The agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community.

The Yucca Mountain Draft EIS is not in compliance with numbers 2, 3, or 4 above. While DOE has stated that information used in determining the groundwater flow model is incomplete or unavailable, the existing credible scientific evidence relevant to evaluating reasonably foreseeable significant adverse impacts has not been summarized nor has it all been utilized in developing flowpaths.

To be in compliance with NEPA, DOE is required to consider effects of credible alternative models in the Draft EIS. While the Draft EIS recognizes differing viewpoints regarding groundwater flow and references the State of Nevada-funded studies of Lehman and Brown, 1995, there has been no evaluation of the impacts. (See Attachment U to these comments for an expanded discussion of this topic.)

Response
DOE believes that the EIS is consistent with the National Environmental Policy Act, as amended (42 U.S.C. 4321 *et seq.*), and with the Nuclear Waste Policy Act, as amended (42 U.S.C. 10101 *et seq.*). DOE acknowledges in several places in the EIS that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, including incomplete or unavailable information, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

Sections 3.1.4.2.1 and 3.1.4.2.2 discuss opposing views on groundwater conditions and groundwater boundaries. Although DOE disagrees with the central scientific conclusions of these opposing views, it continues to support research in several areas and on other aspects of the geology and hydrology of the region to enhance the Department's understanding of the site.

7.5.3.2 (5858)
Comment - 010422 / 0002
[Have full disclosure of] what the specific geology of the proposed storage area as well as expert opinion on the suitability of the property for storage.

Response
Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. This description includes the opinions of many experts who have reviewed and provided input to the site characterization process. Based on the results of analyses reported in Chapter 5 of the EIS concerning the long-term performance of the repository, DOE believes that a repository at Yucca Mountain would operate safely; that is, in compliance with the Environmental Protection Agency's *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada*, at 40 CFR Part 197. Under the Nuclear Waste Policy Act, it is the Secretary of Energy's responsibility to either recommend or not recommend the Yucca Mountain site to the President for construction of a repository. The Secretary will base the decision on the vast amount of information collected by DOE and other agencies during the past several decades.

7.5.3.2 (5874)
Comment - EIS001622 / 0018
Need for More Thorough Evaluation of Potential Groundwater Impacts in California

Inyo County, California testified before DOE on the long-term threat that the Yucca Mountain repository poses to regional groundwater supplies and to communities east of Owens Valley. Studies conducted by Inyo County and Nye and Esmeralda Counties in Nevada point to the existence of a continuous aquifer running from beneath Yucca Mountain south to Tecopa, Shoshone and Death Valley Junction. These studies indicate that water flowing beneath Yucca Mountain flows generally south to become surface water and groundwater flowing into Death Valley that is used for commercial and domestic purposes and supports natural habitats. Some of these springs also support populations of a number of threatened or endangered species.

In addition to determining potential pathways for radionuclides, the DEIS should evaluate the effect of DOE's proposed groundwater extraction in Jackass Flats on the flux or rate of flow of groundwater to discharge areas of the regional aquifer in California. The groundwater extraction proposed at Jackass Flats will eventually exceed the perennial yield that has been defined in the DEIS. All extraction, even that which does not exceed perennial yield, will decrease the amount of water that flows through the aquifer and is discharged at down-gradient springs and wetlands. This decrease would almost certainly affect such habitat deleteriously.

The source of water at Jackass Flats will be supplied by (1) more water entering the groundwater system (increased recharge), (2) less water leaving the system (decreased discharge, and/or (3) removal of water that was stored in the system, or some combination of these three. It is unlikely that recharge will increase. Since recharge will probably not increase, we are left with the conclusion that less water will be discharged from the aquifer, and the amount of groundwater in storage will be decreased. Both of these results will decrease the down-gradient groundwater supply from the regional aquifer to springs and wetlands.

Recommendation: The DEIS should more fully evaluate potential pathways for radionuclides reaching regional groundwater supplies in eastern California, such as in the Death Valley region. The DEIS should evaluate the above-referenced studies and include them in their analyses of the potential migration of radionuclide contaminants to regional groundwater supplies. The DEIS should also include a discussion of proposed methods, including monitoring wells and water resource studies, to determine the amount of change in flux that can be expected, the potential effects of that change on aquatic and riparian habitat and water supply, and proposed mitigation procedures.

Response

The EIS recognizes that the region's groundwater flowpath includes the locations identified in this comment, with the exception of the Owens Valley area. Section 3.1.4.2.1 describes the flowpath for groundwater beneath Yucca Mountain to be to Jackass Flats to the Amargosa Desert, and then south to the primary point of discharge at Alkali Flat (Franklin Lake Playa) southeast of Death Valley Junction. The EIS also recognizes that some groundwater reaching this far might bypass this playa area and continue into the Death Valley basin, which would require moving through the Tecopa and Shoshone areas. The EIS recognizes that a small fraction of the groundwater flow beneath the Amargosa Desert might flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains toward spring discharge points in the Furnace Creek Wash area of Death Valley.

Chapter 5 of the EIS does not specifically address risks to people and natural resources that might be experienced in the Tecopa, Shoshone, or Death Valley National Park areas as a result of groundwater use and consumption. However, the evaluation presented in Chapter 5 shows that risks would decrease with increased distance from the repository site. Accordingly, impacts to these other areas, because they are farther away on the groundwater flowpath, would be less than those for the furthest distance evaluated in the EIS. Section 5.9 addresses impacts to biological resources as a result of the long-term performance of the repository. As indicated in this section, DOE did not quantify impacts to biological resources as a result of exposures to contaminated groundwater, but did relate them to the minimal impacts expected for humans through the use and consumption of the groundwater.

As described in Section 3.1.4 of the EIS, the Death Valley regional groundwater flow system is a terminal hydrologic basin. That is, there is no natural pathway for water (groundwater or surface water) to leave the basin other than by evaporation or transpiration through plants, and Death Valley is the low area for the basin. With this in mind, impacts to groundwater of the area east of Owens Valley would be unlikely as a result of the Proposed Action. Depending on the specific location of concern, it would be outside the Death Valley regional groundwater flow system (DIRS 100131-D'Agnese et al. 1997) or its groundwater flows toward the same basin in Death Valley National Park. (That is, groundwater from Yucca Mountain would have to flow down to the Death Valley basin and back up-gradient to reach areas east of Owens Valley that are outside of the Park.)

Section 4.1.3 of the EIS addresses the relatively short-term impacts associated with the extraction of groundwater to support the operational phases (that is, construction, operations and monitoring, closure) of the proposed repository. (These are considered short-term in comparison to those dealing with the long-term performance of the proposed repository that are discussed in Chapter 5.) As identified in Section 4.1.3.3, the peak projected annual water demand for the repository action [360,000 cubic meters (290 acre-feet)], when combined with projected demand from the

Nevada Test Site [350,000 cubic meters (280 acre-feet)], would approach, but would not exceed, the lowest estimate of perennial yield for the western two-thirds of the Jackass Flats hydrographic area [720,000 cubic meters (580 acre-feet)]. This combined withdrawal rate would be well below the highest estimates of the perennial yield of this area. Section 4.1.3.3 recognizes that groundwater withdrawal at Jackass Flats would, to some extent, reduce the amount of underflow that would reach down-gradient areas. However, it also discusses that the first area to experience an impact would be the area of the Amargosa Desert, and that the amount of water required by the repository action is very small in comparison to the amount of groundwater already being withdrawn in that area.

Since the publication of the Draft EIS, additional efforts have taken place to model the impacts of the proposed repository's groundwater withdrawals on the regional groundwater. Results of these efforts, which predict relatively minor changes in both water elevation outside of the Yucca Mountain area and in the amount groundwater flux into Amargosa Desert, are now described in Section 4.1.3.3 of the EIS.

7.5.3.2 (5887)
Comment - EIS001622 / 0020
Need for Hydrogeologic Cross-Section and Water Level Maps

The DEIS does not contain a hydrogeologic cross-section--a basic tool for evaluating the potential impact of contaminates on groundwater--to help evaluate potential groundwater migration from the proposed repository into the Amargosa and Death Valleys. The EIS should include the cross-section as well as maps showing water level isocontours. Without this information, potential environmental impacts to groundwater in California cannot be reasonably assessed. In addition, the DEIS' characterization of the carbonate aquifer in the vicinity of Yucca Mountain is insufficient. It appears that only a single well completed in this aquifer was tested. This method does not provide reliable data on groundwater flow direction or aquifer hydraulic conductivity. More field data are needed to enhance the computer-modeling effort. Without the actual parameters of the aquifer, it is difficult to judge the model's reliability for predicting the fate and transport of radionuclides 10,000 years into the future.

Recommendation: The DEIS should include a hydrogeologic cross-section and maps showing water-level isocontours to help evaluate potential groundwater migration from the proposed repository into the Amargosa and Death Valley regions. More field data on groundwater flow direction or aquifer hydraulic conductivity are needed to enhance the computer modeling effort.

Response
DOE agrees with this comment on the importance of developing hydrogeologic cross sections and water-level isocontour (or potentiometric surface) maps. The Department did not include more of this type of information in the Draft EIS to keep the discussion as simple and brief as possible. However, as a result of this comment and others, Section 3.1.4 of the Final EIS contains a potentiometric surface map of the region and a hydrogeologic cross section simplified from the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000). DOE believes that the EIS text provides a simplified description consistent with those in the hydrogeologic cross sections.

With respect to the second part of the comment, DOE plans to acquire additional characterization data for the carbonate aquifer. The Nye County Nuclear Waste Repository Project Office has embarked on an independent verification, testing, and oversight drilling program that includes the Early Warning Drilling Program. Information from the ongoing site characterization program and from the performance confirmation program (if Yucca Mountain is approved for a repository), would be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information (see Section 3.1.4.2.1 of the EIS).

7.5.3.2 (5932)
Comment - EIS001622 / 0036
Section 3.1.4.1.2 DOE correctly notes that precipitation is not uniform either spatially or temporarily at the site; e.g., most recharge occurs during the winter months. However, DOE never provides an estimate of the volume of water flux through the mountain, nor, is enough data available to determine what part of the mountain will be

affected by the so-called “fast paths” through the mountain. DOE needs to provide information on the water flux through Yucca Mountain and the most probable areas affected by the “fast paths” in the unsaturated zone.

Response
Section 3.1.4.2.2 discusses volume of water flux through Yucca Mountain. With regard to possible “fast-flow” pathways through the mountain, DOE has used a variety of naturally occurring isotopes (for example, chlorine-36) to investigate this process. Results to date have detected elevated amounts (values above normal background measurements) of “bomb-pulse” chlorine-36 in several places in the Exploratory Studies Facility from nuclear testing conducted during the 1950s and 1960s, principally in the Pacific. The locations where this bomb-pulse chlorine-36 has been detected in the Exploratory Studies Facility are associated generally with known through-going faults and well-developed fracture systems close to those faults. This suggests that connected pathways exist through which surface precipitation has percolated to the repository horizon within the last 50 years.

DOE based the selection of the proposed repository block in large part on the lack of mapped surface faults in this part of Yucca Mountain. In light of the close association of the detection of chlorine-36 with mapped surface faults, DOE does not anticipate the presence of many undiscovered fast paths. Continued chlorine-36 sampling in the cross drift that would extend above the repository has not identified additional fast paths. The fast paths identified to date have been factored into the Total System Performance Assessment for the repository.

7.5.3.2 (5935)
Comment - EIS001622 / 0039
Section 3.1.4.2.2. It is significant that the character of the pore water from the rock matrix is chemically distinct from water found in fractures. It is also significant that water in the perched zones does not appear to receive a large contribution from the rock matrix; indicating all significant flow, both in terms of volume and velocity, is via fracture flow through the mountain. DOE should estimate at what level of precipitation (infiltration) fracture flow becomes the dominant flow path.

Response
The characteristics of the pore water and perched water have been very helpful in determining how water moves through the unsaturated zone at Yucca Mountain. However, DOE believes that the comment that “all significant flow, both in terms of volume and velocity, is via fracture flow through the mountain” is an over simplification. Water movement in the unsaturated zone at Yucca Mountain is controlled by the structure and characteristics of each geological formation, or layer, it encounters. In some layers, fracture flow is the predominant mechanism; in at least one layer, however, matrix flow is much more important, even dominant.

Infiltration and percolation have been studied extensively at Yucca Mountain. The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) discusses field investigations and model development in this area. These studies are difficult to conduct at Yucca Mountain because the low precipitation and high evapotranspiration rates are not conducive to direct measurements of infiltration, but they have shown that infiltration at the surface is highly variable, both temporally and spatially. They have enabled DOE to develop a conceptual model of how water moves through the unsaturated zone if it gets deep enough to avoid surface, or near-surface, evapotranspiration. The conceptual model, supported by field data as well as numerical models, indicates that water moves through the Tiva Canyon welded unit and Topopah Springs welded unit (where the underground repository would be located) is predominantly through fractures and faults. Lying in between these two units is the Paintbrush nonwelded unit. Matrix flow is the dominant flow mechanism through the Paintbrush nonwelded unit because of its relatively high matrix permeability and porosity and low fracture density (DIRS 151945-CRWMS M&O 2000). Matrix flow through this unit substantially attenuates the downward movement of percolating water. The chlorine-36 studies, discussed in Section 3.1.4.2.2 of the EIS, suggest that quick pathways (less than 50 years) extending to the underground repository are associated with fractures or faults cutting through the Paintbrush nonwelded unit. Data collected also indicate that the lateral movement of water at the top of this unit is minor and, accordingly, the amount of water moving down through faults and fractures is small compared to that moving through the matrix.

This conceptual model of water percolation is supported by data gathered during efforts to determine the age of the perched water that lies below the level of the proposed repository. The age of this water is estimated to be thousands of years; too young for water moving solely through the matrix and too old for water moving predominantly via fractures and faults. The conceptual model for water percolation at Yucca Mountain would indicate that the perched water is a mixture of water of different ages. Some of the water has had its travel time attenuated as a result of matrix flow, whereas some water has traveled relatively fast through faults and fractures.

7.5.3.2 (5937)
Comment - EIS001622 / 0040
Table 3-14. Calling the basal vitrophyre and the Tram Tuff confining units seems to be little more than wishful thinking. Apparent hydraulic conductivities up to 40 m/yr. in the Tram Tuff are not that much different than the underlying carbonate aquifer ("described as a "a regionally extensive aquifer system through which large amounts of groundwater flow") displaying a permeability of 69 m/yr. Water percolating through the mountain will take the path of least resistance; therefore, the higher permeability value for the Tram Tuff is probably more indicative of its "typical" permeability.

Response
The apparent hydraulic conductivity of up to 40 meters per year cited by the commenter refers to those bedded tuffs, lava flows, and flow breccias beneath the Tram Tuff, not to the Tram Tuff itself (EIS Table 3-14). Evidence supporting the view that these hydrogeologic units act as a confining layer comes from pressure and temperature measurements conducted in borehole UE-25 p#1. This 1,800-meter (6,000-foot)-deep borehole penetrates the deep Paleozoic carbonate aquifer, exhibits excess pressure head [approximately 17 meters (56 feet)] and elevated temperature compared to measurements of these parameters in virtually all other boreholes in the vicinity of Yucca Mountain. In addition, the chemistry of water from this borehole unambiguously identifies the water as coming from the regional carbonate aquifer. All other water samples taken from boreholes that bottom in the lower volcanic aquifer and lower volcanic confining unit exhibit a chemical signature distinctly volcanic. Isolation of these two chemical systems is strong evidence for the bedded tuffs, lava flows, and flow breccias acting as an effective confining unit.

Similarly, aquifer pumping tests conducted in that part of the lithologic section that includes the basal vitrophyre of the Topopah Spring Tuff and the Calico Hills-Prow Pass nonwelded tuffs (collectively, the upper volcanic confining unit) produce only modest amounts of water compared to the overlying and underlying hydrogeologic units (considered to be aquifers). Additional evidence of the resistance to flow that these units possess is in the unsaturated zone, where the basal vitrophyre and portions of the Calico Hills serve as layers upon which perched water has accumulated.

7.5.3.2 (5938)
Comment - EIS001622 / 0041
Section 3.1.4.2.2, Page 3-52. DOE states that "the actual and relative amounts of inflow [into the volcanic aquifers below Yucca Mountain] from each (of the four potential) sources are not known." This is an essential piece of information necessary for any effective modeling of groundwater flow from beneath the mountain and toward Franklin Playa. Any model lacking this information would not provide a meaningful or reliable characterization of groundwater flow.

Response
DOE has conducted an extensive site characterization program to evaluate the proposed repository at Yucca Mountain. During site characterization the Department has performed tests to develop a defensible site-scale saturated-zone flow and transport model. The *Saturated Zone Flow and Transport Process Model Report* (DIRS 145738-CRWMS M&O 2000) and subsequent updates summarize this model. Chapter 2 of that report discusses the evolution of the saturated-zone process model. In particular, Section 2.5 summarizes the current saturated-zone flow and transport model. Chapter 3 of the report describes model development and Section 3.2.2 presents boundary conditions. The site-scale flow and transport model is compatible with the regional-scale model described by D'Agnese et al. (DIRS 100131-1997), the Hydrogeologic Framework Model, and available data on recharge within the site-scale model area. Most of the inflows and outflows from the site-scale saturated-zone model occur as flow across the lateral boundaries. The best available estimates of flow rates are cell-by-cell fluxes calculated by the regional-scale model for the site-scale model, then calibrated against known data points in the model domain. The text in question has been revised to better reflect new data from individual locations have been integrated into models to development estimates of the saturated zone water balance.

7.5.3.2 (5939)
Comment - EIS001622 / 0042
Section 3.1.4.2.2, Page 3-56. The data from Well JF-2a are troublesome. Why would this well exhibit a 27cm increase in elevation when all the other wells in the area exhibit 3- to 9-cm decreases? This apparent contradiction is glossed over in the text and not discussed except to relate the well locations to the proximity of Fortymile Wash. If wells JF-12, JF-13, and JF-3 were not pumped would their static levels also increase? By not providing an explanation of these static water levels, DOE indicates that the hydrogeology below and directly downgradient of Yucca Mountain is poorly understood. More data is necessary to both understand the down gradient hydrogeology and as input to more meaningful groundwater modeling.

Response
The comment is correct that the Draft EIS did not highlight a potentially key piece of information about well JF-2a. As shown in Figure 3-17, this well is in the carbonate aquifer. There is a possibility that the water elevation in the well has not yet reached an equilibrium condition. DOE has added a sentence to the text to describe this possibility. The primary intent of Section 3.1.4.2.2, however, is to state the findings to date from the applicable reference, which is a recommendation for additional monitoring to determine if the water levels are correlated to a causative action or condition.

The reference material that DOE used did not correlate water level fluctuations with proximity to Fortymile Wash. The Draft EIS mentioned Fortymile Wash in this context only because it had been identified as an area of periodic recharge (see the Inflow to Volcanic Aquifers at Yucca Mountain discussion in Section 3.1.4.2.2). The reference to the wells' proximity to Fortymile Wash has been removed.

7.5.3.2 (5940)
Comment - EIS001622 / 0043
Section 4.1.3.2 There is some discussion here that water percolating into the repository drifts [if any] would be pumped to the surface. What is the maximum volume of water expected to percolate into the drifts?

Response
The average percolation flux under present conditions is about 5 millimeters (0.2 inch) per year and the capillary-barrier effect of the excavation of the drifts should cause a diversion of this percolating water around the excavated drifts. Therefore, it is uncertain if any water would seep into the drifts that would require pumping to the surface. Additional evidence of the overall lack of fluid flow in the subsurface is that throughout the excavation of more than 11 kilometers (6.8 miles) of tunnels for the Exploratory Studies Facility, only one fracture was moist. Further observations in testing alcoves that have been isolated from the effects of tunnel ventilation for several years confirm the lack of natural seepage at the waste-emplacement level. In summary, despite finding millions of fractures in the course of excavation at Yucca Mountain, there is scant evidence that even modest quantities of water penetrate to waste-emplacement depths.

7.5.3.2 (5943)
Comment - EIS001622 / 0047
In summary, the hydrogeologic and geochemical characterization of Yucca Mountain and vicinity is not complete. Major uncertainties remain about the "fast paths" through the mountain and the flow paths from the underlying volcanic and carbonate aquifers to the alluvial aquifer in Amargosa Valley and possibly on to Death Valley. It is also unclear what effect the Ghost Dance fault (and other faults) east of the proposed facility could have on ground water flow. Currently, the ground water modeling performed on these flow paths, based on little or no information, is little more than conjecture.

Response
DOE continues to evaluate the "fast paths" through the mountain by experimentation and verification of chlorine-36 sampling, as described in Section 3.1.4.2.2 of the EIS. Results of the verification sampling and continued experimentation, if available, are presented in the Final EIS and supporting documents.

The Draft EIS was developed using the best available information for hydrochemical and geochemical characterization. Many experiments are ongoing and some of the resulting data are included in the EIS. DOE recognized that the saturated zone requires additional characterization in order to fully evaluate the effects of faults on flowpaths and the relationships between the alluvial/valley fill aquifer, volcanic aquifer, and carbonate aquifer systems. DOE initiated a Cooperative Agreement with Nye County to address a number of the characterization uncertainties mentioned in this comment and has included the available data into the Final EIS. The Nye County program is described below.

DOE has supported Nye County with it's program (called the *Early Warning Drilling Progra*m) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain, as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the performance confirmation program (if Yucca Mountain was recommended and approved for a repository) could be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information (see Section 3.1.4.2.1 of the EIS).

In addition, DOE has installed a series of test wells along the groundwater flow path between the Yucca Mountain site and the Town of Amargosa Valley as part of an alluvial testing complex. The objective of this program is to better characterize the alluvial deposits beneath Fortymile Wash along the east side of Yucca Mountain. Single- and multiwell tracer tests have begun and the results thus far have strengthened the basis of the site-scale saturated flow and transport model. Information from this program has been incorporated in the EIS.

DOE realizes that the data obtained from the Nye County Cooperative Agreement Early Warning Drilling Program are critical to understanding the saturated zone system and performance assessment calculations south of Yucca Mountain. All data obtained from the Nye County Early Warning Drilling Program would be utilized to the extent possible for the enhancement of the saturated zone models. DOE scientists would perform sorption studies on lithologic material extracted from Nye County boreholes for incorporation into the saturated zone transport model and abstraction into the performance assessment calculations. DOE would use chemical data to enhance current studies on the understanding of saturated flow systems and various hydrochemical facies. Groundwater elevation data would continue to be determined from all wells and would be used to define flow and transport paths, calibration of models, and support the geologic framework model.

7.5.3.2 (5944)
Comment - EIS001622 / 0046
It is amazing that, in a project that is to completely characterize the subsurface in and around Yucca Mountain, there has been no high-resolution geophysical surveys conducted to further delineate the geologic structures below Yucca Mountain that may enhance (of hinder) ground water flow. We recommend that such surveys be conducted as a very cost-effective way of gathering useful subsurface geologic information.

Response
DOE used several geophysical methods, including seismic reflection, gravity, and magnetic surveys, to characterize the subsurface geologic structure of Yucca Mountain at and near the repository. A single magnetotelluric line and several vertical seismic profiles provided supplementary information.

In the Yucca Mountain area, DOE conducted a 32-kilometer- (20-mile)-long seismic reflection survey across Bare Mountain, Crater Flat, Yucca Mountain, Midway Valley, and Fortymile Wash. Where this regional profile crosses the repository site, the reflection data show a series of west-dipping normal faults that displace volcanic rocks and the Tertiary/pre-Tertiary contact at depth. DOE collected gravity data from geophysical surveys and used these data to interpret regional structure and to aid in the interpretation of shallow structures at Yucca Mountain, such as the location of and displacement along faults. The Department conducted ground magnetic surveys at Yucca Mountain to estimate the location of faults and the displacement along these faults. Because buried faults and geologic heterogeneities at Yucca Mountain could affect the long-term performance of the repository, DOE used magnetotelluric methods to detect and characterize these features.

DOE combined the information from these geophysical studies with the results of other field studies, including detailed geologic mapping of the surface and in the Exploratory Studies Facility. In addition, boreholes drilled at the site supplied information on the vertical and lateral distribution of hydrogeologic units, hydrologic properties of the rocks, thermal and other geophysical conditions and properties, chemistry of the contained fluids, pneumatic pressure, and water content and potential. Additional data for some of these parameters came from excavations for the Exploratory Studies Facility and from boreholes drilled in drifts and alcoves of the Exploratory Studies Facility.

Using this combined data set, DOE derived detailed geologic and hydrologic models that describe the spatial models of rock layers, faults, rock properties, and mineral distributions in the subsurface and to simulate three-dimensional fluid flow and support site-performance models of Yucca Mountain. For a more complete discussion of site scale geophysical studies, see Section 4.6.5 of the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000).

7.5.3.2 (5955)
Comment - EIS001622 / 0056
The DEIS is not consistent in its evaluation of environmental consequences over long time intervals. It takes current predictions and projects them into the future to be used in the long-term analysis. For example, in the last paragraph p. 5-23 the DEIS concludes that no contamination of the carbonate aquifer is possible because there is currently an apparent hydraulic head of 120 feet in this aquifer forcing water up into the volcanic aquifers, therefore no contamination of surface springs in California would occur. This does not consider the potential for a future change in hydraulic gradients due to climate change, seismicity, etc., over very long periods of time. The potential of surface water contamination from groundwater should be more rigorously evaluated and potential impacts described.

Response
A discussion was added to Section 5.3 to address your concerns. In particular, the "Saturated Zone Process Model Report" dedicates a chapter to changes in the saturated zone flow system (DIRS 145738-CRWMS M&O 2000). In that chapter the changes in climate, tectonics, water table elevation, groundwater flux, recharge, and discharge are addressed. These changes are considered for a time period of 10,000 years. Under these scenarios, the conclusion remains the same; no contamination would occur in the discharge areas of the carbonate aquifer system.

7.5.3.2 (5956)
Comment - EIS001622 / 0063
The risk assessment indicates that Amargosa and Death Valleys are the points of discharge of volcanic and carbonate aquifers into the alluvial aquifer used as a water source by the local population. However, according to some publications (e.g., USGS OFR 83-542) most of the water recharged into Amargosa Valley alluvial aquifer is from snow melt and rainfall from the surrounding mountains. The EIS should provide support for either of these two cases: that the majority of recharge is from surface recharge or that it is from underflow from the volcanic and/or carbonate aquifers.

Response
DOE recognizes that precipitation falling at higher elevations in the surrounding mountains is often cited as the primary source of the water in the Amargosa Desert alluvial aquifer. In addition, surface waters in the area are described as ephemeral, with flowing water only in response to heavy precipitation or in localized areas supplied by springs. Some might consider this a contradiction, but the primary source of the water in the alluvial aquifer is from water recharged at higher locations. Groundwater recharged at higher elevations reaches the Amargosa Desert as underflow by the pathways, or aquifers, described in Section 3.1.4 of the EIS.

The report *Water for Nevada* (DIRS 103016-State of Nevada 1971) identifies and quantifies estimates of surface water and groundwater resources for each hydrographic area in the state. For the Amargosa Desert (Hydrographic Area Number 230), the report identifies sources of surface water as being less than 50 acre-feet (about 61,700 cubic meters) per year as runoff from mountains and "some" (unquantified) surface-water inflow from other hydrographic areas. The report identifies sources of groundwater for this area as 600 acre-feet (about 740,000 cubic meters) per year from direct precipitation and 44,000 acre-feet (about 54.3 million cubic meters) per year as groundwater inflow from other hydrographic areas, particularly Mercury Valley, Rock Valley, Jackass Flats, and Crater Flat. These areas are at relatively high elevations and are groundwater conduits for recharge at even higher elevations farther away. All the studies and reports of which DOE is aware indicate that groundwater that originates in adjacent hydrographic areas is the primary source for the groundwater of the Amargosa Desert.

7.5.3.2 (5961)
Comment - EIS001622 / 0060
The draft EIS's risk assessment related to groundwater consumption is based on groundwater migration from the proposed Yucca Mountain repository into the Amargosa and Death Valleys. The draft EIS does contain some information on the regional geology of the Yucca Mountain area. However, the draft EIS does not contain a hydrogeologic cross-section, a basic tool for evaluation of potential impact of contaminants on groundwater. It appears that there is enough information about the area to prepare such a cross-section. Therefore, the EIS should be modified to include: a single, regional, hydrogeological cross section showing the piezometric surface along the potential pathway of groundwater flow; geological formations; the relationships among the volcanic, alluvial and carbonate aquifers; and the outflow locations of carbonate aquifer springs down-gradient from the site. The EIS should also include maps showing water level isocontours. Together, these maps and the cross-section would convey a conceptual model of the site hydrogeologic conditions. Without such maps and cross-sections potential environmental impacts cannot be reasonably assessed.

Response
DOE agrees with the commenter. Section 3.1.4 of the Final EIS includes a potentiometric surface map of the region and a simplified hydrogeologic cross-section.

7.5.3.2 (5962)
Comment - EIS001622 / 0061
The draft EIS appears to contain contradictions regarding which aquifer is present at the actual repository site. For example on page 3-48, the draft EIS states that the saturated zone at Yucca Mountain has three aquifers: upper volcanic, lower volcanic, and lower carbonate aquifer. However, the last two sentences of this paragraph indicate that only two aquifers are present as follow: "The lower volcanic aquifer discussed here corresponds to the middle volcanic aquifer shown in Figure 3-15. The lower volcanic aquifer shown in Figure 3-15 has not been identified in the area of the proposed repository."

The upper volcanic aquifer shown in Figure 3-15 does not occur at the site (Topopah Spring Welded Unit - host rock for the repository). However, because the upper volcanic aquifer occurs down-gradient of the site, the EIS should address the potential pathway of contaminated plume across different hydrogeologic units, including aquicludes and faults.

Response
DOE faced a problem in presenting a simplified picture of the groundwater hydrology at Yucca Mountain because previous studies have not been consistent in their nomenclature. The Department nevertheless believes that the EIS description of aquifers at Yucca Mountain is not contradictory, although it does try to explain one inconsistency in aquifer designations. The paragraph referred to in the comment describes three aquifers, two in the volcanic sequences and one in the carbonate formation. It then indicates that at the repository site the rock unit making up the upper volcanic aquifer is above the saturated zone due to its tilt. Two sentences at the end of the paragraph explain that the sequence forming the lower volcanic aquifer in Figure 3-15 of the Draft EIS has not been found at Yucca Mountain (that is, the middle volcanic aquifer in Figure 3-15 is the lower volcanic aquifer described in the text, and the lower volcanic aquifer described in Figure 3-15 is not present at Yucca Mountain).

Chapter 5 of the EIS summarizes long-term repository performance including contaminant modeling efforts. In addition, the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) contains more detail on the contaminant pathways included in the model. With respect to the specific comment, Section 3.7.1.4 of the Viability Assessment indicates that DOE believes the flow in the saturated zone is primarily through the fractured tuffs of the middle volcanic aquifer (the lower volcanic aquifer described in the EIS) and the valley fill alluvium.

7.5.3.2 (6063)
Comment - EIS001898 / 0009
DOE should correct areas of discrepancy in water use data and provide clarifying information regarding the potential for and impacts from overdrafts of groundwater in the FEIS.

Basis:

Table 3-11 notes that the figures for current water appropriations do not include Federal reserved water rights (FRRs) for the NTS and Nellis AFR. These FRRs should be added to the total appropriations for a more accurate measure of committed resources.

Table 3-11 and DEIS Section 3.1.4.2.1 (Affected Environment - Regional Groundwater) suggest that ample water is available for new appropriations to support the Proposed Action because average annual withdrawals (actual use) are well below the appropriation limits. Although the use of average withdrawals may be appropriate, it is possible that this could be misleading because users are entitled to withdraw or sell their full appropriations.

When discussing the water demands expected during performance confirmation in Section 4.1.3.1 (Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure -- Impacts to Hydrology from Performance Confirmation) the DEIS omits mention of NTS and Nellis AFR wells in the area. The pumpage from those wells should be added to that from J-11 and J-12 and the C-well complex in the proposed land withdrawal area for an improved estimate of the water demand. The wide range in the perennial yield figures (880 to 4000 acre-feet for Area 227a) should be explained. The perennial yield and committed resources figures for Area 227a in Nevada Division of Water Planning (1992) do not agree with Table 3-11. DOE should provide additional justification for the perennial yield figures, considering the variance from information in other sources, to support its assessment of potential overdraft in the region.

The discussion of water demand during construction, operation and monitoring, and closure in Section 4.1.3.3 (Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure -- Impacts to Groundwater from Construction, Operation and Monitoring, and Closure) of the DEIS also should be clarified. This discussion should make clear where the water will be obtained to meet the combined water demand for the repository, the NTS, and Nellis AFR. Under one scenario, the perennial yield of Area 227a would be exceeded. The text should be clarified to explain the impacts of any possible overdraft.

The discussion in DEIS Section 4.1.3.3 (Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure -- Impacts to Groundwater from Construction, Operation and Monitoring, and Closure) includes at least one scenario where the Jackass Flats basin would be in overdraft status. In addition, Table 3-11 presents the Amargosa Desert Area 230 in a potential overdraft situation. DOE (1996) confirms that historic data show that DOE withdrawals at Yucca Flats have annually exceeded the perennial yield. The potential impacts of these overdrafts should be discussed.

DOE should correct discrepancies in water-use discussions and data in the FEIS. The evaluation of groundwater use during construction, operation, and monitoring should include a discussion of the potential for overdrafts.

References:

Nevada Division of Water Planning. *Nevada Water Facts, 1992.* 241353. Carson City, NV: Nevada Division of Water Planning. 1992.

U.S. Department of Energy, *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Location sin the State of Nevada.* DOE/EIS-0243-F,239895. Las Vegas, NV: U.S. Department of Energy. 1996.

Response

Federal Reserve Water Rights are noted in the footnote to Table 3-11, but are not quantified because they are not directly comparable to water appropriations authorized by the State of Nevada. As stated in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996), the Federal Reserve Water Rights position is that the Nevada Test Site is "…entitled to withdraw the quantity of water necessary to support the NTS missions." The Nevada Test Site EIS does not quantify or limit these rights, except for their purpose, and the repository EIS concurs with this view. With respect to identifying committed water resources, the repository EIS is obligated to identify cumulative impacts of other Federal and non-Federal actions. Chapter 8 discusses the past, present, and foreseeable future actions and associated water demands. In this manner, the EIS does indirectly identify quantities of water expected to be associated with reserved water rights (that is, if their impacts would be cumulative with those of the Proposed Action).

The purpose of Table 3-11 of the Draft EIS and its associated text is not to suggest that ample water is available. The intent is only to describe existing groundwater resources and use in the region of Yucca Mountain. DOE agrees that average withdrawals do not tell the entire story when looking at groundwater resources and their availability. This is the reason that both water appropriations and estimates of perennial yield are also shown in the table. In addition, DOE understands, though not expressed in the EIS, that the State Engineer must consider factors in addition to those shown in the table when considering requests for water appropriations.

Chapter 8 of the EIS describes the cumulative impacts of groundwater use by the Nevada Test Site, Nellis Air Force Range, and the proposed repository. Additional text has been added to Section 8.2.3.2 to better address other uses of groundwater in the area. As identified in Section 4.1.3.3, the peak projected annual water demand for the proposed action [360,000 cubic meters (290 acre-feet)], when combined with projected demand from the Nevada Test Site [350,000 cubic meters (280 acre-feet)], would approach, but would not exceed, the lowest estimate of perennial yield for the western two-thirds of the Jackass Flats hydrographic area [720,000 cubic meters (580 acre-feet)]. The corresponding discussion in Section 4.1.3.1 of the EIS (impacts from performance confirmation) is intentionally brief because of the relatively small annual water demand projected for that phase of the project. The evaluation in this section compares projected water demand to the perennial yield estimates and shows them to be minor. The addition of the Nevada Test Site demand would still put projected water withdrawals well below the lowest estimates of perennial yield, which were not mentioned.

With respect to the wide range of perennial yield figures identified for hydrographic area 227a, an explanation of the origin and basis for each of these numbers is beyond the scope of the EIS. A partial answer is that estimates of recharge are difficult and vary widely in this area where evapotranspiration is high and quantities of surface water are low. An order of magnitude difference between recharge estimates for the same study area is not unusual in the literature. The source of the perennial yield information presented in Table 3-11 of the Draft EIS is in a footnote to the table. The cited source identifies the studies from which the perennial yield values are taken and discusses those studies. The EIS recognizes that the Nevada Division of Water Planning uses an estimate of perennial yield that is not totally consistent with those listed in Table 3-11. Tables 3-35 and 3-43 of the Draft EIS both include a footnote indicating that the Nevada Division of Water Planning uses a combined perennial yield of 30 million cubic meters (24,000 acre-feet) for hydrographic areas 225 through 230. This estimate was not used in the tables because it has not been divided into the individual areas. DOE thought it important to give estimates and discuss perennial yield based on these smaller areas, so it used the best available data (on an individual hydrographic area basis). DOE believes that the EIS considers a wide range of perennial yield values, particularly for hydrographic area 227a (Jackass Flats), and that this is appropriate and conservative. The fact that the Nevada Division of Water Planing uses different values for some of the committed resources is due to the use of a more recent reference in the EIS (DIRS 103406-NDWP 1992).

As indicated above, Chapter 8 of the EIS discusses other (nonrepository) water demands in the Yucca Mountain region. However, Section 4.1.3.3 does clearly indicate that there would be an ongoing Nevada Test Site water demand from the same hydrographic area from which the Yucca Mountain Site Characterization Project would be withdrawing water. This section does not mention water demands for the Nellis Air Force Range because there are no demands in this hydrographic area. It does discuss the potential for overdraft of this hydrographic area. This hydrographic area (227a – Jackass Flats) is not an isolated basin. It receives water both from the surface (recharge from precipitation) and as underflow from upgradient areas. It also loses water as underflow to downgradient areas. As described in the EIS, withdrawing only slightly more water than the low estimate of perennial yield (which is based solely on recharge from local precipitation) would be unlikely to cause a depletion of the reservoir because of the higher quantities estimated to be moving through as underflow. However, it would probably result in a minor shifting of the general groundwater flow patterns to compensate. Since the publication of the Draft EIS, two groundwater modeling efforts have been completed to simulate the effects of the projected water demands by the repository on the groundwater flow system. The Final EIS has been modified to discuss the results of these efforts, which are consistent with the general impacts discussed above.

As indicated above, effects of overdrafting within Jackass Flats are discussed in this EIS and modifications have been added to the Final EIS to address the results of applicable modeling efforts. With respect to the Amargosa

Desert, Section 4.1.3.3 of the EIS states that water demand associated with the proposed repository would have only a small impact on water availability in Amargosa Desert. That is, actual or potential overdrafting of groundwater in the Amargosa Desert would be attributed predominantly to pumping in that area and would not be substantially affected by the amount of water needed to support the repository. Accordingly, possible impacts from overdrafting in Amargosa Desert are not discussed in the EIS. Overdrafting at Yucca Flat is not described in the EIS because it does not have a direct connection to the Proposed Action. Figure 3-13 of the Draft EIS shows that Yucca Flat is within the Ash Meadows Groundwater Basin and the direction of groundwater flow from there is toward Frenchman Flat and eventually to the Ash Meadows area and, if remaining as underflow, to the Amargosa Desert. This is consistent with the State of Nevada report *Water for Nevada* (DIRS 103016-State of Nevada 1971), which shows no groundwater inflow to this hydrographic area (area 159 – Yucca Flat), but does show its groundwater outflow going to Frenchman Flat, which also receives underflow from adjacent areas. The Nevada Test Site withdraws water from Frenchman Flat (hydrographic area 160), but at quantities far below its perennial yield (DIRS 101811-DOE 1996). Based on this picture of groundwater flow conditions, overdrafting at Yucca Flat would be expected to result in very localized conditions, probably not even extending far into Frenchman Flat because the combined water use for these two areas (Yucca and Frenchman Flats) is only a small fraction of their combined perennial yield [1.8 million cubic meters (1,400 acre-feet) of peak annual water demand versus 16,350 acre-feet of perennial yield (DIRS 101811-DOE 1996)]. Any affects on the groundwater flow from Yucca Flat overdrafting would surely be lost by the time groundwater flow reaches the southern end of the Amargosa Desert where impacts could be cumulative with those of the Proposed Action. Accordingly, Chapter 8 discusses impacts of the total water demand and cumulative impacts from the Nevada Test Site and the Proposed Action and does not address noncumulative issues that are internal to the Test Site.

7.5.3.2 (6135)
<u>Comment</u> - EIS001654 / 0020
Page S-39. What is the Groundwater Risk?

The discussion about groundwater admits to uncertainties about the groundwater flow system in the region of the repository. The text does not address the on-going work being conducted by Nye County that will presumably reduce some of that uncertainty.

The wording of section S.4.1.4 is a little too opaque, it seems to us. In describing what would pose a threat to groundwater, the text says a “contaminant” would have to be spilled or released and then carried down by its own weight or by infiltrating water. Then it says the arid climate and depth to groundwater combine to reduce the potential contaminant migration. This section should be expanded and linked to discussions elsewhere about the specific (and only?) “contaminant” that is the dominant long-term concern for this repository: the contaminants of concern are radionuclides.

We have heard testimony at the various public hearings about risks to groundwater contamination due to theorized release projections of radionuclides. We have seen opinions expressed but we are unable to judge what factual basis there is for what seems like a branch of science in which uncertainty continues even as more data becomes available. Maybe better answers won’t be available until the testing program results are analyzed or during the licensing application review process. Until then, it would seem that the section on groundwater could be improved to better educate the public than the current wording does.

<u>Response</u>
The commenter is correct about the work that Nye County will conduct. DOE has supported Nye County with it’s program (called the *Early Warning Drilling Program*) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain, as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the performance confirmation program (if Yucca Mountain is approved for a repository), could be used in conjunction with that of the Early Warning Drilling Program to refine the Department’s understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information (see Section 3.1.4.2.1 of the EIS).

DOE agrees that additional clarification is appropriate for the contaminant migration. Section S.4.1.4 is intended to summarize discussions in Section 4.1.3 of the EIS that cover potential impacts associated with the active phases of the proposed repository action (that is, construction, operation and monitoring, and closure). Chapter 5 of the EIS discusses long-term, postclosure impacts, including the potential for radionuclide migration. DOE has modified the text in the Summary.

7.5.3.2 (6182)
Comment - EIS000929 / 0004
The Draft EIS states, "There is scientific uncertainty about the exact locations of the groundwater flow boundaries." In the next paragraph, it states, "The depth to groundwater and the arid environment [of the Yucca Mountain site] would combine to reduce the potential for meaningful contaminant migration." I'm not following this logic: "We really don't know where the groundwater is going, but we're sure it won't be contaminated...much." In addition, the Nye County Department of Natural Resources indicates that radioactivity from the US Ecology commercial low-level waste disposal facility has been detected off-site. If this is happening at a low-level waste facility, how can we be assured it will not happen at the Yucca Mountain site?

Response
DOE has conducted an extensive site characterization program to evaluate the suitability of Yucca Mountain for a repository. During site characterization, the Department has performed numerous tests to develop a reasonable model of site-scale saturated-zone flow and transport. The latest version of the model is summarized in the *Saturated Zone Flow and Transport Process Model Report* (DIRS 151948-CRWMS M&O 2000) and subsequent technical updates. Chapter 2 of that report discusses the evolution of the saturated zone process model. In particular, Section 2.5 summarizes the current saturated zone flow and transport model. Section 3 of the report presents the details of the model development in which the boundary conditions are presented in Section 3.2.3. The site-scale flow and transport model is designed to be compatible with the regional-scale model described by D'Agnese et al. (DIRS 100131-1997), to use the Hydrogeologic Framework Model, and to use available data on recharge within the site-scale model area. Most of the inflows to and outflows from the site-scale saturated zone flow model occur as flow across its lateral boundaries. The best available estimates of flow rates are cell-by-cell fluxes calculated by the regional-scale model for the site-scale model, then calibrated against known data points in the model domain.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information). The EIS based its analysis of impacts on a state-of-the-art modeling technique that is internationally recognized as an adequate and proper approach. The results of this analysis, described in Chapter 5 of the EIS, indicate that impacts would be low. Appendix I of the EIS and supporting documents contain details of the analysis methodology. See Sections 3.1.4.2.1 and 5.4 of the EIS for additional information.

7.5.3.2 (6282)
Comment - EIS001639 / 0007
The EIS makes use of "bulk permeabilities" in their analysis of groundwater flow and contaminant transport. The use "bulk" or average transport times tends to reduce the real effects of groundwater contamination. The study ignores the fact that groundwater flow will predominate through preferential pathways that exhibit the fastest not the "bulk" permeabilities. Thus the report tends to elucidate the average rather than the worst case scenario.

Response
The EIS does not describe the use of bulk permeabilities in its analysis of groundwater flow and contaminant transport. The only use of this terminology that could be found was in Section 3.1.3.1, Geology, where it is stated that the joints and fractures common in welded tuffs result in "greater bulk permeabilities than those of the nonwelded and bedded tuffs." That is, the rate of water movement in the welded tuffs is increased by the presence of joints and fractures.

The EIS does, however, describe the importance of groundwater flow through fractures (the fast pathway described in the comment) in developing models of flow and contaminant transport. These discussions are in Chapter 5 of the EIS. Specifically, Section I.2.2 describes how modeling of the long-term performance of the repository had to account for water movement in the unsaturated zone being through both the rock matrix and rock fractures, with the latter flow being much more rapid. Section I.2.2 of the EIS contains additional information on how these two flow mechanisms were accommodated by use of a dual-permeability model. Refer to Volume 3, Section 3.1.1, of the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) for a more detailed description of the dual-permeability model and its flexibility to represent a wide range of matrix-versus-fracture flow behavior. In addition, the Viability Assessment contains a detailed description of how flow in the saturated zone was modeled. Again, the discussion describes how the saturated zone model had to account for movement through fractured media where flow and contaminant movement would occur primarily through fractures.

7.5.3.2 (6456)

Comment - EIS001632 / 0020

Section 3 of the draft EIS provides information about the hydrogeologic conditions in the vicinity of Yucca Mountain. The certainty of this information varies considerably, and it is difficult for the reader to understand how uncertainties will be resolved and how the data still being gathered will affect the design of the repository and the projections for ground water contamination. EPA [Environmental Protection Agency]suggests that the final EIS summarize ongoing studies and their expected impact on design and on ground water quality projections.

Response

DOE believes that it has sufficient information and understanding of the hydrologic setting to adequately determine the potential environmental impacts from the Proposed Action. DOE and others have been evaluating and assessing the hydrologic setting and associated characteristics at the Yucca Mountain site and nearby region for many years. DOE's site characterization program has been redirected from time-to-time to reflect and accommodate reviews by independent parties, both internal and external to the Department. Nevertheless, it is clear that the regional and site-specific hydrologic setting is complex and uncertainties remain. Additional information would refine DOE's understanding of, for instance, the regional groundwater flow system, and would further reduce uncertainties associated with flow and transport in the alluvial, volcanic and carbonate aquifers.

In recognition of these uncertainties, DOE has supported Nye County with its program (called the *Early Warning Drilling Program*) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain, as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the performance confirmation program (if Yucca Mountain is approved for a repository) could be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information (see Section 3.1.4.2.1 of the EIS).

In addition, DOE has installed a series of test wells along the groundwater flow path between the Yucca Mountain site and the Town of Amargosa Valley as part of an alluvial testing complex. The objective of this program is to better characterize the alluvial deposits beneath Fortymile Wash along the east side of Yucca Mountain. Single- and multi-well tracer tests have begun and the results thus far have strengthened the basis of the site-scale saturated flow and transport model. This program is described in Section 3.1.4.2.1 of the EIS.

Although DOE has improved its understanding of the hydrologic system, uncertainties would remain given the time frame of concern (waste isolation for thousands of years). If the site was approved, DOE would institute a *performance confirmation and testing program*, elements of which would address the hydrologic system. The purpose of this program would be to evaluate the accuracy and adequacy of the information used to determine whether the repository would be expected to meet long-term performance objectives. The performance confirmation program, which would continue through closure of the repository (possibly as long as 300 years), would offer a means to further understanding of the hydrologic system and reduce uncertainties.

7.5.3.2 (6457)
Comment - EIS001632 / 0021
Most of the ground water studies described in Section 3 were done on a regional scale and may not provide accurate site-specific data for the saturated zone beneath the proposed repository. Section 3 provides general statements about ground water data, but fails to inform the reader about aquifer-specific data, such as the length of time data have been collected on the carbonate aquifer and the number of wells sampled over various periods of time. This information is particularly important for modeling the transport of radionuclides in the saturated zone.

Response
DOE has initiated a program to evaluate the hydrologic processes in the saturated zone, particularly the hydrogeologic relationship between the volcanic aquifer, alluvial aquifer, and carbonate aquifer. This is currently being addressed through a cooperative agreement between Nye County and DOE, referred to as the Early Warning Drilling Program. Recent results from this program have been incorporated into this Section 3.1.4.2.1 of the EIS.

Section 3.1.4.2.2 of the EIS refers to large hydraulic gradient north of the site. Specific information related to the saturated zone and carbonate aquifer can be found in the cited references in Section 12 of the EIS. With regard to the saturated zone and the carbonate aquifer, one well (UE 25p #1) penetrated the carbonate aquifer at Yucca Mountain, another well (NC-EWDP-2DB), along the potential flow path in Fortymile Wash, has penetrated the carbonate aquifer and an upward hydraulic gradient was present. Well NC-EWDP-2DP, along with six additional planned wells, will help characterize the carbonate aquifer system near Yucca Mountain as part of the Nye County Early Warning Drilling Program. Four other wells at Yucca Mountain, as reported by Luckey et al (DIRS 100465-1996), are believed to indicate the potentiometric level in the carbonate aquifer. Elsewhere in the general area, particularly at the southern end of the Nevada Test Site and eastward from the springs in Ash Meadows, the hydraulic relationship between the lower carbonate aquifer and overlying units is well understood (DIRS 101167-Winograd and Thordarson 1975). The very presence of the springs in Ash Meadows demonstrates the fact of an upward hydraulic gradient in the lower carbonate aquifer. Because the lower carbonate aquifer is buried by some 6,000 feet of unconsolidated deposits in the Amargosa Desert west of the springs in Ash Meadows, no wells have been drilled into this aquifer. Claassen (DIRS 101125-1985) presents the hydraulic and hydrochemical evidence of subsurface discharge from the lower carbonate aquifer to the alluvial fill of the Amargosa Desert to the west of Rock Valley Wash. In addition, several investigations have concluded from hydrologic, chemical, and isotopic evidence that the lower carbonate aquifer is the source of the large springs in Furnace Creek Wash (Death Valley). Thus, the understanding of the flow system and hydraulic relationships of the lower carbonate aquifer are based not only on data from well UE 25p #1 at Yucca Mountain, but on a large body of regional hydrologic and chemical evidence collected over the past 40 years.

7.5.3.2 (6459)
Comment - EIS001632 / 0023
Page 3-41, Section 3.1.4.2.2: This section describes the Topopah Spring tuff unit, in which repository will be built, as fractured, very permeable, and extensively interconnected; and, perched water forms at its contact with the underlying Calico Hills non-welded unit. Page 3-48 states that water chemistry analysis has found that "perched water reached its current depth with little interaction with rock. This, in turn, provides strong evidence that flow through faults and fractures is the primary source of perched water." The final EIS should address this concern: if seismic activity occurred at these fault zones, water could move faster (or slower) through the faults and fractures, possibly increasing the mounding of perched water. This is different than the "upwelling" referred to on page 3-49.

Response
Section 3.1.4.2.2 of the EIS indicates that perched water is formed when water percolating down through the subsurface encounters a zone of lower permeability and, as a result, accumulates. Vertical movement of water probably stills occurs, but at a slower rate below the perched water than above. In the tilted strata at Yucca Mountain, the accumulation of perched water must be accompanied by a feature such as a fault to restrict the lateral movement of water. The surface of the perched water then remains at a fairly stable elevation once the inflow and outflow rates are balanced. At Yucca Mountain this is attributed to less infiltration (a drier climate than when most of the perched water accumulated) and/or the elevation of the perched water reaching a point where the lateral restriction changes and the water "spills" out, or it could just reflect a long-term, steady-state condition.

The commenter is correct that seismic activity could change the rate at which water moves in the unsaturated zone, but it would be much less likely to change the quantity of water moving through the unsaturated zone because quantity is related chiefly to climate. That is, the rate at which water would reach the perched zone might increase for a short period of time as water above it "drained" from the system as a result of increased permeability. But eventually the amount of water reaching the perched water would again be controlled by the amount of water entering the system (that is, infiltration). For either the short-term increase in flux or the long-term climate-driven flux to cause significant "mounding" of the perched water, the seismic activity would have to result in a decreased permeability below the perched zone and/or an extension (lengthening) of the lateral restriction to flow. A scenario of increased perched water elevation is not addressed in the EIS because neither of these conditions would be expected to occur to any significant extent as a result of seismic activity. Compared to the overlying Topopah Spring welded unit, seismic activity might cause less fracturing in the Calico Hills nonwelded unit (the unit causing the perching condition), but it would not be expected to decrease the latter's permeability. The barrier to lateral flow at faults is believed to be the result of the juxtaposition of a more permeable layer against a less permeable layer caused by the fault displacement. Therefore, to lengthen the barrier, the offset would have to be lengthened. This is an obvious result of displacement, but the greatest displacement in the Yucca Mountain area [32-centimeter (13-inch); Section 3.1.3.3 of the EIS] would be exceeded less than once in 100,000 years. Correspondingly, fault displacement would not be expected to significantly increase the depth of perched water.

DOE has considered hundreds of "what if" scenarios involving features, events, and processes (FEPs) and how they might affect the long-term performance of the repository. Those scenarios not excluded because of low probability or low consequences or for other reasons were subjected to more detailed analysis and included in long-term performance modeling. This process is documented in DOE's FEP database and associated documentation. The FEP process does not specifically address "mounding" of the perched water, but it does cover what is believed to be a more realistic scenario; the relatively rapid draining of the perched water due to seismic activity. In this case, were such an event to take place after containers in the repository had begun to degrade, it could result in a fast pulse of contamination reaching the saturated zone. This scenario was excluded from analysis in the long-term performance modeling because it was reasoned that the volume of water associated with the perched system is not great enough to cause a significant "pulse" to the saturated zone.

7.5.3.2 (6461)
Comment - EIS001632 / 0024
Page 3-46: The final EIS should provide an up-to-date analysis of the chlorine-36 transport data.

Response
As part of its site characterization activities, DOE has conducted a variety of investigations into the nature of water falling as precipitation on Yucca Mountain and passing through the unsaturated zone to the groundwater beneath. One such study has been to quantify the concentrations of certain radioisotopes in the Exploratory Studies Facility. Isotopes, such as chlorine-36 and tritium, which occur naturally and as a byproduct of atmospheric nuclear weapons testing, serve as indicators of the rate of flow through the unsaturated zone (see Section 3.1.4.2.2 of the EIS for details).

Results from preliminary studies have identified these isotopes in concentrations that tend to suggest that there are connected pathways through which surface precipitation has percolated to the repository horizon within the last 50 years. However, these isotopes have been found at locations that are generally associated with known, through-going faults and well-developed fracture systems close to the faults at the proposed repository horizon.

To ensure the correct interpretation of this chemical signal, DOE instituted additional studies to determine if independent laboratories and related isotopic studies can corroborate the detection of elevated concentrations of these radioisotopes. Results of the validation studies to this point have not allowed firm conclusions and, thus, the evaluations continue.

DOE believes that these findings do not indicate that the Yucca Mountain site should be declared unsuitable for development as a repository. Most of the water that infiltrates Yucca Mountain moves slowly through the matrix and fracture network of the rock, and isotopic data from water extracted from the rock matrix indicates that residence times might be as long as 10,000 years. Furthermore, after excavating more than 11 kilometers (8.4 miles) of tunnels at Yucca Mountain for the Exploratory Studies Facility, DOE determined that only one fracture was moist (there was no active flow of water). This observation has been confirmed in test alcoves that are not subject to the effects of drying from active ventilation.

Nevertheless, the total system performance assessment incorporates the more conservative water movement data as well as information from other water infiltration and associated hydrogeological studies. As a result of this evaluation, DOE would not expect the repository (combination of natural and engineered barriers) to exceed the prescribed radiation exposure limits during the first 10,000 years after closure.

7.5.3.2 (6462)
Comment - EIS001632 / 0025
Page 3-49: Lower carbonate aquifer. Since data are limited, the EIS should not conclude that the lower carbonate aquifer has an upward gradient. Page 3-51 states that there is only one transmissivity value based on tests from a single well. Also, on page 3-52, it seems preliminary to count this aquifer as a possible source of inflow to the volcanic aquifers. The final EIS should acknowledge the limited confidence that can be placed on the gradient interpretation with the data currently available.

Response
DOE has started a program to evaluate the hydrologic processes in the saturated zone, particularly the hydrogeologic relationship between the volcanic aquifer, alluvial aquifer, and carbonate aquifer. This is currently being addressed through a cooperative agreement between Nye County and DOE, referred to as the Early Warning Drilling Program. Recent results from this program have been incorporated into this Section 3.1.4.2.1 of the EIS.

With regard to the saturated zone and the carbonate aquifer, one well (UE 25p #1) penetrated the carbonate aquifer at Yucca Mountain, another well (NC-EWDP-2DB) along the potential flow path in Fortymile Wash penetrated the carbonate aquifer and an upward hydraulic gradient was present. Well NC-EWDP-2DP, along with six additional planned wells, will help characterize the carbonate aquifer system near Yucca Mountain as part of the Nye County Early Warning Drilling Program. Four other wells at Yucca Mountain, as reported by Luckey et al (DIRS 100465-1996), are believed to indicate the potentiometric level in the carbonate aquifer. Elsewhere in the general area, particularly at the southern end of the Nevada Test Site and eastward from the springs in Ash Meadows, the hydraulic relationship between the lower carbonate aquifer and overlying units is well understood (DIRS 101167-Winograd and Thordarson 1975). The very presence of the springs in Ash Meadows demonstrates the fact of an upward hydraulic gradient in the lower carbonate aquifer. Because the lower carbonate aquifer is buried by some 6,000 feet of unconsolidated deposits in the Amargosa Desert west of the springs in Ash Meadows, no wells have been drilled into this aquifer. Claassen (DIRS 101125-1985) presents the hydraulic and hydrochemical evidence of subsurface discharge from the lower carbonate aquifer to the alluvial fill of the Amargosa Desert to the west of Rock Valley Wash. In addition, several investigations have concluded from hydrologic, chemical, and isotopic evidence that the lower carbonate aquifer is the source of the large springs in Furnace Creek Wash (Death Valley). Thus, the understanding of the flow system and hydraulic relationships of the lower carbonate aquifer are based not only on data from well UE 25p #1 at Yucca Mountain, but on a large body of regional hydrologic and chemical evidence collected over the past 40 years.

7.5.3.2 (6463)
Comment - EIS001916 / 0003
[Section] (S.4.1.4) Hydrology. The groundwater travel time is too rapid to isolate radioactive particles leading to groundwater contamination due to the fractured nature of Yucca Mountain.

Response
As part of its site characterization program, DOE has used a variety of naturally occurring isotopic indicators, one of which is chlorine-36, to investigate the nature of infiltration and deep percolation of water at the site. Results from this program detected elevated amounts (values above normal background measurements) of “bomb-pulse” chlorine-36 in several places in the Exploratory Studies Facility from nuclear testing conducted during the 1950s and 1960s. The locations where this bomb-pulse chlorine-36 has been detected in the Exploratory Studies Facility are associated generally with known through-going faults and well-developed fracture systems close to those faults. This suggests that there are connected pathways through which surface precipitation has percolated to the repository horizon within the last 50 years. These findings, however, must be viewed in the context of whether waste can be stored safely at Yucca Mountain. Overall, most of the water that infiltrates into Yucca Mountain moves much more

slowly through the matrix and fracture network of the rock. Only a small fraction has moved quickly through the connected portion of the fracture network. Carbon isotope data from water extracted from the matrix correspond to residence times as long as 10,000 years.

The elevated values of bomb-pulse chlorine-36 detected in the subsurface correspond to increases of between about two to eight times the amount of naturally occurring “background” chlorine-36. This background signal is the amount measured in the regional aquifers and in the matrix water of rocks in the unsaturated zone. Furthermore, even elevated bomb-pulse values represent exceedingly minute increases in the amount of chlorine-36. Naturally occurring ratios of radioactive chlorine-36 to the other isotopes of chlorine (chlorine-35 and -37) are about one chlorine-36 atom to approximately 2 trillion other chlorine atoms. Their detection is more a mark of the incredible precision of the analytical methods employed in this study (accelerator mass spectrometry) than it is an indication of an unsuitable environment for the emplacement of high-level radioactive waste. To ensure the correct interpretation of this subtle chemical signal, studies are under way to determine if independent laboratories and related isotopic studies can corroborate this detection of elevated amounts of chlorine.

Another important factor regarding the safety of the emplaced waste is whether percolating water would come in contact with waste packages. The process of drift excavation creates a capillary barrier that could cause percolating water to be diverted around the drift opening, further reducing the amount of water potentially capable of contacting the packages. DOE has been conducting a series of experiments to determine the seepage threshold, which is the amount of water needed to overcome the capillary barrier created due to excavation. Results obtained to date suggest that the expected amounts of percolating water in the repository horizon under the present climate would be too small to exceed the existing capillary barrier.

Additional evidence that attests to the overall lack of observable fluid flow in the subsurface is the fact that throughout the excavation of more than 11 kilometers (8.4 miles) of tunnels and testing alcoves, only one fracture was moist (there was no active flow of water). After collecting and analyzing the moisture from this fracture, DOE detected no bomb-pulse chlorine-36. Only background levels of chlorine-36 were evident, indicating old water. Further observations from test alcoves that have been isolated from the effects of tunnel ventilation for several years, confirm the lack of observable water seepage in the repository horizon. In summary, despite encountering millions of fractures in the course of excavations, there is scant evidence that even modest quantities of water penetrate to repository depths.

DOE’s original 1984 site suitability guidelines (10 CFR Part 960) have been superseded by Yucca Mountain-specific guidelines (10 CFR Part 963) promulgated by DOE in 2001. Even though 10 CFR Part 960 no longer applies to Yucca Mountain, DOE believes that information and analyses do not support a finding that the site would have been disqualified under the groundwater travel time disqualifying condition at 10 CFR 960.4-2-1(d). Under that condition, a site would be disqualified if the expected groundwater travel time from the disturbed zone (the area in which properties would change from construction or heat) to the accessible environment would be less than 1,000 years along any pathway of likely and significant radionuclide travel. The definition of groundwater travel time in 10 CFR 960.2 specifies that the calculation of travel time is to be based on the average groundwater flux (rate of groundwater flow) as a summation of travel times for groundwater flow in discrete segments of the system. (In this case, the geologic and hydrologic subunits comprising the unsaturated and saturated zones.) As a practical matter, this definition provides for the consideration of the rate at which most of the water moves through the natural system to the accessible environment.

As part of its site characterization activities, DOE has undertaken various studies to identify and consider characteristics of the unsaturated (above water table) and saturated (water table) zones, such as the flow of water and transport of radionuclides, that are relevant to analyzing groundwater travel times. DOE also has considered physical evidence such as the chemistries and ages of water samples from these zones. Because of the inherent uncertainties in understanding such natural processes as groundwater flow, DOE has developed numerical models to represent an approximation of these processes and to bound the associated uncertainties.

Based on these models, which incorporate the results of these studies and available corroborating physical evidence, DOE estimates that the median groundwater travel times would be about 8,000 years, and average groundwater travel times would be longer. These models indicate that small amounts of water potentially moving in “fast paths” from the repository to the accessible environment could do so in fewer than 1,000 years. However, the models and corroborating physical evidence indicate that most water would take more than 1,000 years to reach the accessible environment. Given this, DOE believes that the site would not have been disqualified under the groundwater travel condition at 10 CFR 960.4-2-1.

The natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa more than 60 kilometers (37 miles) away and travel times to this point would be even longer. Modeling of the long-term performance of the repository shows that the combination of natural and engineered barriers at Yucca Mountain would keep doses resulting from any releases within the regulatory limits established at 40 CFR Part 197.

7.5.3.2 (6464)
Comment - EIS001632 / 0026
Page 3-52: The final EIS should provide data from the ongoing investigations on the cause of the potentiometric difference north and south of the site, and it should describe what these data suggest about the potential for water from the north to flood the repository.

Response
Section 3.1.4.2.2 of the EIS refers to the large hydraulic gradient north of the Site. An expert elicitation panel addressed this feature and narrowed its likely cause to two theories: (1) flow through the upper volcanic confining unit or (2) semi-perched water. The consensus of the panel favored the perched-water theory. Whatever the cause, the experts were in agreement that the probability of any large transient change in the configuration of this gradient is extremely low (DIRS 100353-CRWMS M&O 1998). DOE has initiated a program to evaluate the hydrologic processes in the saturated zone, particularly the hydrogeologic relationship between the volcanic aquifer, alluvial aquifer, and carbonate aquifer. This is currently being addressed through a cooperative agreement between Nye County and DOE, referred to as the Early Warning Drilling Program. Recent results from this program have been incorporated into Section 3.1.4.2.1 of the Final EIS.

7.5.3.2 (6465)
Comment - EIS001632 / 0027
Page 3-57: In the discussion about water levels in the 7 wells, the significance of their proximity or distance to Fortymile Wash is unclear.

Response
The reference from which DOE extracted this information does not correlate water-level fluctuations with proximity to Fortymile Wash. The Draft EIS mentioned this only because Fortymile Wash is an area of periodic recharge, which could have a local, temporary affect on the elevation of groundwater (see Section 3.1.4.2.2 of the EIS). The reference to the wells' proximity to Fortymile Wash has been removed.

7.5.3.2 (6468)
Comment - EIS001632 / 0029
Page 3-31: We are confused about the discussion of the Amargosa River system and the statement that there is a ground water discharge near Beatty, NV. The final EIS should clarify the direction of the ground water flow which, according to Figure 3-13 (page 3-38), does not appear to be in the direction of Beatty.

Response
Section 3.1.4.1.1 of the EIS discusses surface water in the region of Yucca Mountain and indicates that groundwater discharges to the channel of the Amargosa River near the community of Beatty, Nevada. The purpose of this discussion is only to identify areas along the river channel where surface water exists on a regular basis. It is not to identify the source of the groundwater that supplies the flow; this information is included in the discussion of regional groundwater in Section 3.1.4.2.1 of the EIS (which includes Figure 3-13). In the discussion of Basins in Section 3.1.4.2.1, the description of the Pahute Mesa-Oasis Valley groundwater basin indicates groundwater outflow is southward to the Amargosa Desert. The flow arrow shown in Figure 3-13 of the Draft EIS at the south end of the Pahute Mesa-Oasis Valley basin points southward toward Amargosa Desert and shows the groundwater pathway to be beneath the community of Beatty. Accordingly, groundwater discharged in the area of Beatty comes from the Pahute Mesa-Oasis Valley basin.

7.5.3.2 (6479)

Comment - EIS001774 / 0002

The Yucca Mountain site which is supposed to be isolated from the water aquifer theoretically for thousands of years has been found with rainwater that contains contaminants that are man-made and date from the last 40 years. The movement of rain water through the Yucca Mountain site should, according to federal officials, disqualify it as a site. The 1992 earthquake destroyed the Yucca Mountain press center. This should give you a clue that the site is much more than a public relations disaster, it is an environmental disaster waiting to happen.

Response

As part of its site characterization activities, DOE has conducted a variety of investigations into the nature of water falling as precipitation on Yucca Mountain and passing through the unsaturated zone to the groundwater beneath. One such study has been to quantify the concentrations of certain radioisotopes in the Exploratory Studies Facility. Isotopes, such as chlorine-36 and tritium, which occur naturally and as a byproduct of atmospheric nuclear weapons testing, serve as indicators of the rate of flow through the unsaturated zone (see Section 3.1.4.2.2 of the EIS for details).

Results from preliminary studies have identified these isotopes in concentrations that tend to suggest that there are connected pathways through which surface precipitation has percolated to the repository horizon within the last 50 years. However, these isotopes have been found at locations that are generally associated with known, through-going faults and well-developed fracture systems close to the faults at the proposed repository horizon.

To ensure the correct interpretation of this chemical signal, DOE instituted additional studies to determine if independent laboratories and related isotopic studies can corroborate the detection of elevated concentrations of these radioisotopes. Results of the validation studies to this point have not allowed firm conclusions and, thus, the evaluations continue.

DOE's original 1984 site suitability guidelines (10 CFR Part 960) have been superseded by Yucca Mountain-specific guidelines (10 CFR Part 963) promulgated by DOE in 2001. Even though 10 CFR Part 960 no longer applies to Yucca Mountain, DOE believes that information and analyses do not support a finding that the site would have been disqualified under the groundwater travel time disqualifying condition at 10 CFR 960.4-2-1(d). Under that condition, a site would be disqualified if the expected groundwater travel time from the disturbed zone (the area in which properties would change from construction or heat) to the accessible environment would be less than 1,000 years along any pathway of likely and significant radionuclide travel. The definition of groundwater travel time in 10 CFR 960.2 specifies that the calculation of travel time is to be based on the average groundwater flux (rate of groundwater flow) as a summation of travel times for groundwater flow in discrete segments of the system. (In this case, the geologic and hydrologic subunits comprising the unsaturated and saturated zones.) As a practical matter, this definition provides for the consideration of the rate at which most of the water moves through the natural system to the accessible environment.

As part of its site characterization activities, DOE has undertaken various studies to identify and consider characteristics of the unsaturated (above water table) and saturated (water table) zones, such as the flow of water and transport of radionuclides, that are relevant to analyzing groundwater travel times. DOE also has considered physical evidence such as the chemistries and ages of water samples from these zones. Because of the inherent uncertainties in understanding such natural processes as groundwater flow, DOE has developed numerical models to represent an approximation of these processes and to bound the associated uncertainties.

Based on these models, which incorporate the results of these studies and available corroborating physical evidence, DOE estimates that the median groundwater travel times would be about 8,000 years, and average groundwater travel times would be longer. These models indicate that small amounts of water potentially moving in "fast paths" from the repository to the accessible environment could do so in fewer than 1,000 years. However, the models and corroborating physical evidence indicate that most water would take more than 1,000 years to reach the accessible environment. Given this, DOE believes that the site would not have been disqualified under the groundwater travel condition at 10 CFR 960.4-2-1.

Furthermore, after excavating more than 11 kilometers (6.8 miles) of tunnels at Yucca Mountain, DOE determined that only one fracture was moist (there was no active flow of water). Further observations from testing alcoves isolated from effects of tunnel ventilation for several years confirm the lack of observable natural seepage at the repository level.

Nevertheless, the total system performance assessment incorporates the more conservative water movement data as well as information from other water infiltration and associated hydrogeological studies. As a result of this evaluation, DOE would not expect the repository (combination of natural and engineered barriers) to exceed the prescribed radiation exposure limits during the first 10,000 years after closure.

Another important factor regarding the safety of emplaced waste is whether percolating water would actually come in contact with waste packages. The process of drift excavation creates a capillary barrier that causes a diversion of percolating water around the drift opening, further reducing the amount of water potentially capable of contacting waste packages. DOE has been conducting a series of experiments to determine the seepage threshold, the amount of water necessary to overcome the capillary barrier created due to excavation. Results to date suggest that the expected amounts of percolating water at the repository level might be insufficient to exceed the existing capillary barrier.

The Little Skull Mountain earthquake of 1992, which is the largest recorded earthquake within 50 kilometers (31 miles) of Yucca Mountain (Richter magnitude 5.6), caused no damage at Yucca Mountain. It did damage the Yucca Mountain Field Operations Center in Jackass Flat, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), but this facility was not built to the seismic-design specifications planned for the facilities at Yucca Mountain. DOE is designing surface facilities associated with the proposed repository with extremely conservative margins of safety to ensure safe operation regardless of the potential for strong seismic occurrences.

7.5.3.2 (6484)
Comment - EIS001632 / 0035
Page 4-25, Section 4.1.3.3: The assessment of impacts to ground water should reference the discussion on radionuclide transport in ground water in Section 5.2. Readers may be confused by the page 4-25 discussion which focuses on the impact from spills and the potential for a contaminant to infiltrate and percolate through the unsaturated zone, rather than on the full range of ground water contamination.

Response
DOE concurs with this suggestion. Cross-references to Chapter 5 have been added to Section 4.1.3.3 to avoid confusion between short-term preclosure effects and long-term performance after closure.

7.5.3.2 (6521)
Comment - EIS001813 / 0004
The DOE has failed to take into consideration the potential for severe health related consequences related to possible groundwater contamination. Simply denying that the groundwater will not become contaminated and that the population will not grow is not acceptable and renders the current DEIS unacceptable. Therefore, the DOE must not recommend the development of a geologic repository at Yucca Mountain.

Response
Appendix F describes the health effects from radiation. DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

7.5.3.2 (6553)
Comment - EIS001632 / 0047
Page 5-13: Section 5.2.3.4 discusses the different paths radionuclides can take, but should discuss pathways through the alluvial, volcanic and carbonate aquifers.

Response
The intent of Section 5.2.3.4 of the Draft EIS (Sections I.2.2 and I.2.8 of the Final EIS) is to describe the process models and radionuclide movement tendencies. Section 3.1.4.2.1 provides aquifer and pathway information.

7.5.3.2 (6555)
Comment - EIS001632 / 0048
Page 5-23: This section states "Because of this pressure difference, water from the volcanic aquifer does not flow into the carbonate aquifer; rather the reverse occurs." This statement relies on just one data point in the carbonate aquifer. In Chapter 3, this uncertainty was noted. One data point does not provide certainty, and the EIS should not assume that the entire carbonate aquifer has an upward gradient, given the amount of fracturing and faulting involved. Nor should the EIS state that no contamination will occur at Ash Meadows, since Chapter 3 noted that it was a discharge point.

Response
DOE recognizes that additional data would further define the flow system and reduce uncertainties about the interactions among the alluvial, volcanic, and carbonate aquifers in the saturated zone. DOE has initiated a program to evaluate the hydrologic processes in the saturated zone, particularly the hydrologic relationships between the volcanic aquifer, alluvial aquifer, and carbonate aquifer. This is currently being addressed through a cooperative agreement between Nye County and DOE, referred to as the Early Warning Drilling Program. Recent results from this program have been incorporated into Section 3.1.4.2.1 of the Final EIS.

It is correct that only one well penetrates the lower carbonate aquifer at Yucca Mountain. Four other wells at Yucca Mountain, as reported by Luckey et al (DIRS 100465-1996), are believed to indicate the potentiometric level in the carbonate aquifer. Additional wells are being drilled to characterize the carbonate aquifer system near Yucca Mountain as part of the Early Warning Drilling Program. One of the wells drilled under this program, which is about 19 kilometers (12 miles) south of the repository site, also penetrated the carbonate aquifer and shows an upward gradient at that location.

With regard to the comment on Ash Meadows, groundwater that infiltrates through Yucca Mountain does not discharge at the Devils Hole Protective Withdrawal or in Ash Meadows. The elevation of the water table in the Devils Hole/Ash Meadows area is about 64 meters (210 feet) higher than the water table in the Amargosa Desert to the west and south. This east-to-west decline in the elevation of the water table indicates that groundwater from the carbonate rocks beneath the Devils Hole Hills flows westward across Ash Meadows toward Amargosa Desert--not the other way around. Therefore, contaminants from Yucca Mountain could not discharge at springs in Devils Hole and Ash Meadows nor contaminate the aquifer.

7.5.3.2 (6557)
Comment - EIS001632 / 0049
Page 5-27, second paragraph and Page 5-31, bottom paragraph: Page 5-27 states that 22 acre-feet of water per year infiltrate through the repository, while page 5-31 cites 25 acre-feet. Which value is correct?

Response
This comment identifies the infiltration rates for the high and intermediate thermal loads. The amount of infiltration, or flux, that would go through the proposed repository would vary based on the thermal loads being considered. Sections 5.4.1, 5.4.2, and 5.4.3 of the Draft EIS address the high, intermediate, and low thermal load scenarios, respectively. For each scenario, the footprint of the repository (that is, the size of the repository perpendicular to downward moving infiltration) expands to a larger size to support the lower waste loading. With the high thermal load scenario, the waste would be tightly packed and an estimated 27,000 cubic meters (22 acre-feet) of water would infiltrate through the repository. An estimated 31,000 cubic meters (25 acre-feet) of water would go through the repository under the intermediate thermal load scenario. With a low thermal load repository, the waste would be spread out and an estimated 57,000 cubic meters (46 acre-feet) of water would infiltrate through the repository. The same concept is applicable to the higher-and lower-temperature operating modes, which influence the size of the underground emplacement and, therefore, the estimated quantity of water that would infiltrate.

7.5.3.2 (6725)
Comment - EIS001522 / 0003
Another reason that it is problematic for the DOE to assert that the environmental impacts of a permanent, high-level nuclear waste repository will be small is that the DOE admits that repository flooding would be catastrophic, and yet that Yucca Mountain experienced a wetter and cooler period 10,000 to 50,000 years ago (DEIS, 1999, 3-49); if the repository area was flooded 10,000 years ago, then it is reasonable to believe it could be flooded again, in the future, especially because the climate changes appear to be cyclic. Even the DOE admits that climate change at Yucca Mountain is uncertain, and that "the record shows continual variation, often with very rapid jumps, between cold glacial … and warm interglacial climates" (DEIS, 1999, 5-17).

DOE's alleging that the impacts of Yucca Mountain will be small also is inconsistent with its own statements when it reported the findings of Dublyansky (1998) that warm upwelling water has infiltrated the Yucca repository site (DEIS, 1999, 3-49). In response to these findings, the DOE notes that "both parties [the DOE, which supports the repository, and the state of Nevada, which opposes it] have agreed that additional research is needed to resolve the issues [surrounding this upwelling finding] (DEIS, 1999, 3-50). If the DOE thus admits that the upwelling data need to be resolved, and if such repository flooding would be catastrophic, then the DOE cannot consistently claim that effects of Yucca Mountain will be minor. In addition, the DOE admits that the data on Yucca Mountain are sparse and contradictory; for example, the DOE says that "there are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts" (DEIS, 1999, 3-127). Given such discrepancies, it is inconsistent, controversial, and therefore premature to say that building a repository in such an area will cause few environmental impacts.

On the issue of repository flooding, it is interesting to note that the DOE itself claims that "The potential for flooding at the repository site is extremely small" (DEIS, 1999, 4-19), even though its own claims in the preceding paragraph cast doubt on this issue. In particular, if the claims are correct, then it is impossible to know whether the potential for flooding is small or great until the upwelling data are resolved.

Response
This comment deals with two widely different phenomena under the single term "flooding," namely (1) surface flooding by streams and (2) inundation of the proposed repository due to a rise of the water table. To avoid confusion, this response uses "flooding" to represent that due to stream flow, and "inundation" to represent the effect of a rising water table.

DOE agrees that the Yucca Mountain area has experienced several wetter periods over the past 500,000 years. However, it does not agree with the assertion that the proposed waste-emplacement areas were inundated 10,000 years ago. To investigate this hypothesis further, DOE requested the National Academy of Sciences conduct an independent evaluation. The Academy concluded in its 1992 report (DIRS 105162-National Research Council 1992) that no known mechanism could cause a future inundation of the waste-emplacement areas.

DIRS 106963-Szymanski (1989) proposed that during the last 10,000 to 1,000,000 years, hot mineralized groundwater was driven to the surface by earthquakes and volcanic activities. This hypothesis goes on to suggest that similar forces could raise the regional groundwater in the future and inundate the waste-emplacement areas. The features cited by Szymanski as proof of groundwater upwelling in and around Yucca Mountain are related to the much older (13-10 million years old) volcanic process that formed Yucca Mountain and the underlying volcanic rocks.

Significant water-table excursions (exceeding tens of meters) to the waste emplacement areas from earthquakes would be unlikely. As discussed in EIS Section 3.1.3.1, the likelihood of volcanic activity in the area is low (one chance in 70 million annually), and would raise the water table a few tens of meters, at most.

DOE scientists have estimated that the water table could rise by 50 to 130 meters (160 to 430 feet) under extremely wet climatic conditions. The regional aquifer has been estimated to have been a maximum of 120 meters (390 feet) above the present level beneath Yucca Mountain during the past million or more years based on mineralogic data, isotopic data, discharge deposit data, and hydrologic modeling. An earthquake under these extreme climatic conditions could cause an additional rise in the water table of less than 20 meters (66 feet), still leaving a safety margin of 20 meters (66 feet) or more between the water table and the level of the waste emplacement areas. The

1992 Little Skull Mountain earthquake (magnitude 5.6), raised water levels in monitoring wells at Yucca Mountain a maximum of less than 1 meter (3.3 feet) (DIRS 101276-O'Brien 1993). Water level and fluid pressure in continuously monitored wells rose sharply and then receded over several hours to pre-earthquake levels. The water level rise in hourly monitored wells was on the order of centimeters and indistinguishable after 2 hours (DIRS 101276-O'Brien 1993).

Regarding Dr. Dublyansky's alternative interpretation (DIRS 104875-Dublyansky 1998), the fact that the EIS cites his report is not a DOE endorsement of his theory. As explained in Section 3.1.4.2.1, DOE arranged a review of Dr. Dublyansky's work by a group of experts, who disagreed with his theory. However, DOE is not opposed to further research on the topic of fluid inclusions, and is providing financial support to independent research on fluid inclusions by Professor Jean Cline of the University of Nevada-Las Vegas.

The final paragraph of the comment refers to the statement, "The potential for flooding at the repository site is extremely small," in Section 4.1.3 of the EIS. As explained in the introduction to Chapter 4, this analysis deals with a period of 50 to 300 years after receipt of the first radioactive waste. Chapters 5 and 6 deal with the time after closure. The context of the statement is related to flooding by small intermittent streams in the vicinity of the proposed repository, namely Drill Hole Wash and its tributaries, where DOE would build the repository surface facilities. As described in Section 3.1.4.1.2, DOE has analyzed and mapped the potential for flooding. Even the largest floods would not affect the underground repository because the portals would be above potential flood levels. DOE would design surface facilities to accommodate predicted flood levels, so flooding impacts would be limited to temporary interruption of vehicle traffic during the short periods of stream flow.

7.5.3.2 (6735)
<u>Comment</u> - EIS001522 / 0004
The DEIS likewise is scientifically questionable because it substitutes scientific judgment or opinion in areas, like groundwater migration, in which there already is confirmed scientific evidence to the contrary. In the case of groundwater migration, the primary means whereby radionuclides would migrate offsite, the DEIS alleges that, given the groundwater at Yucca Mountain, there would be "minimal potential to involve substantial contaminant releases" (DEIS, 1999, 8-33). This opinion, however, is doubtful because even the DEIS (1999, 3-42) admits that the perched groundwater at Yucca Mountain is very young (and therefore that rapid groundwater migration has occurred): "The apparent age of the perched water based on carbon-14 dating indicates this recharge occurred during the past 6,000 years." If the Yucca Mountain groundwater was recharged during the last 6,000 years, and if the waste is above the groundwater, then it is reasonable to assert that groundwater, migrating through the waste, may recharge the groundwater in the next several thousand years, just as it did in the past. On a related point, the DEIS also admits that

Chlorine-36 analyses at Yucca Mountain have identified locations where water has moved fairly rapidly (in several decades) from the surface to the depth of the proposed repository. About 13 percent of the samples (31 samples) had high enough chlorine-31-to-total-chlorine ratios to indicate the water originated from precipitation occurring in the past 50 years (that is, nuclear age precipitation) (DOE, 1999, 3-47 and 3-48).

After thus noting that much of the groundwater, below the proposed repository, was 50 years old or less, the DEIS admitted that a continuous fracture path in the rock most likely caused this fast transit time (DOE, 1999,3-47). The DOE also noted that, because of the mineral concentrations in the groundwater, there was "strong evidence that flow through faults and fractures is the primary source of the perched water [at Yucca mountain]" (DOE, 1999, 3-48). It is interesting to note that a decade earlier, the DOE (1986, 6-32, 257, 298, 299) was maintaining, contrary to other geological reports, that the transit time from the surface to repository depths would be greater than 10,000 years and that fracture flow was virtually nonexistent. If a mere ten years of research have changed the DOE position on a crucial determinant of repository safety, one can only argue that more research is needed prior to building the repository and that, for now, no action is the best alternative.

It also is interesting to note that the DEIS concludes that, because of slow groundwater migration time, the radionuclides migrating from the Nevada Test Site would result in an individual's receiving only a maximum annual dose of about 0.2 rem, or less than .0l of normal annual background exposure. However, after drawing such a conclusion about minimal impact, the DEIS notes that "there is a high degree of uncertainty associated with this estimate" (DOE, 1999, 8-76). If there is so much uncertainty, then one wonders why the DEIS bothered to give a number that was virtually meaningless. In the same discussion, the DEIS admitted that "the underground tests are based on one data set from one well over a very short time (fewer than 50 years) and then extrapolated to 10,000 years" (DOE, 1999, 8-76). One wonders why the DOE bothered to use such a misleading number, based on one sample, and then extrapolated from less than 50 years to 10,000 years. Such one-well tests and extrapolations are contrary to all good practice in the science of geology (see Shrader-Frechette 1993, 42-50).

Response

As part of its site characterization program, DOE has used a variety of naturally occurring isotopic indicators, one of which is chlorine-36, to investigate the nature of infiltration and deep percolation of water at the site. Results from this program indicate elevated amounts of "bomb-pulse" chlorine-36 associated with nuclear testing during the 1950s and 1960s at a number of underground locations in the Exploratory Studies Facility. These locations are generally associated with known, through-going faults and well-developed fracture systems close to these faults. Detection of elevated levels of chlorine-36 in association with these features could be evidence of a connected pathway through which surface precipitation has percolated to depth within the last 50 years.

These results, however, must be viewed in their proper context regarding the question of whether waste can be stored safely at Yucca Mountain. Overall, most of the water that infiltrates into Yucca Mountain moves much more slowly through the matrix and fracture network of the rock. Only a small fraction has moved through the connected portion of the fracture network with relatively fast travel times. Carbon isotope data from water extracted from the matrix indicate residence times as long as 10,000 years.

The elevated values of bomb-pulse chlorine-36 detected in the subsurface correspond to increases of between about two to eight times the amount of naturally occurring background chlorine-36. This background signal is the amount observed in the regional aquifers and the matrix waters of rocks in the unsaturated zone. Furthermore, even elevated bomb-pulse values represent exceedingly minute increases in the amount of chlorine-36. Naturally occurring ratios of radioactive chlorine-36 to the other isotopes of chlorine (chlorine-35 and -37) are on the order of one chlorine-36 atom to approximately 2 trillion other chlorine atoms. Their detection is more a tribute to the precision of the analytical methods used in this study (accelerator mass-spectrometry) than it is an indication of an unsuitable environment for the emplacement of high-level radioactive waste. To ensure the correct interpretation of this subtle chemical signal, studies are under way to determine if independent laboratories and related isotopic studies can corroborate this detection of elevated amounts of chlorine-36.

Another important factor regarding the safety of emplaced waste concerns whether percolating water would actually come in contact with waste packages. The process of drift excavation creates a capillary barrier that would divert percolating water around the drift opening, further reducing the amount of water potentially capable of contacting waste packages. DOE is conducting experiments to determine the seepage threshold, which is the amount of water necessary to overcome the capillary barrier caused by excavation. Results to date suggest that the amounts of percolating water at the waste-emplacement level are insufficient to exceed the existing capillary barrier.

Additional evidence to the overall lack of observable fluid flow in the subsurface is the fact that throughout the excavation of more than 11 kilometers (6.8 miles) of tunnels and alcoves for the Exploratory Studies Facility, only one fracture was moist. No active flow of water was observed. Further observations from testing alcoves that have been isolated from the effects of tunnel ventilation for several years confirm the lack of seepage at the repository level. In summary, despite encountering millions of fractures in the course of excavation activities, there is scant evidence that even modest quantities of water penetrate to repository depths.

The presence of perched water above the regional water table is a positive factor in relation to the potential transport of radionuclides for the following reasons:

1. The fact that water is perched between the repository horizon and the water table indicates a barrier to flow. In this case, the perching layer possesses less matrix permeability and has a smaller fracture density than the overlying rocks.

2. The age of the perched water is thousands of years despite exhibiting a geochemical and isotopic signature that supports an interpretation of relatively rapid surface-to-depth recharge (tens to hundreds of years). In other words, the perching layer is so effective in impeding the downward flow of water that the water has aged

substantially (thousands of years) in its current location. This increased residence time affords greater opportunity for diffusion and sorption of radionuclides that are potentially released from a breached repository.

The change from the 1986 DOE position on the time it takes water to infiltrate from the surface to depth reflects the increased knowledge gained from more than a decade of surface and subsurface hydrogeologic investigations and associated flow and transport modeling.

The EIS includes an estimate of maximum annual dose from radionuclides migrating from the Nevada Test Site because this dose, even though it is small, contributes to the total dose. In addition, the apparent travel time associated with radionuclides from one nuclear test for which there are travel time data does not consider any effects from "prompt injection" attendant to the detonation of a massive nuclear device. Estimates of groundwater travel times based on isotopic evidence (carbon-14, stable isotopes of hydrogen, carbon, and oxygen) yield much greater travel times.

Although this estimate is based on sparse data, the intent of the effort is to produce a conservative calculation for potential effects due to activities at the Nevada Test Site.

7.5.3.2 (6860)
Comment - EIS001466 / 0006
About the Yucca Mountain site, I do want to say some things about my experience yesterday. I did see the water. It was at the test where the giant heater was heating the rock, and there was water on the floor, water on the walls. This is water in Yucca Mountain that's been driven out of the rock by the heat.

Response
The commenter describes an experience during a visit to the Exploratory Studies Facility Drift Scale Test and reports the presence of water that scientists expected to see during this test. The primary objective of the Drift Scale Test was to develop a more in-depth understanding of coupled thermal-mechanical-hydrological-chemical processes anticipated in the rock mass surrounding the proposed repository. As described in Section I.2.3 of the EIS, the heat generated by the decay of the radioactive materials in the repository would cause the temperature of the surrounding rock to rise. The water in the heated rock would be driven away as vapor from the repository during this period and condense back into water in cooler regions. The thermal output of the waste materials would decrease with time. Eventually, the rock would return to its original temperature, and the water and gas distribution would reach equilibrium with the ambient rock temperature.

The simulated waste packages of the Drift Scale Test in the Exploratory Studies Facility produce a rise in temperature to the surrounding rocks depicting the similar rise in temperature that the decay of radioactive material would cause in the repository. As described above, the commenter observed the condensation of water vapor back to water in the cooler region of the Exploratory Studies Facility.

7.5.3.2 (7277)
Comment - EIS001957 / 0002
Staff at Death Valley National Park have been informed that ongoing studies of the regional groundwater aquifer systems will be terminated with the completion of a steady state model of the Death Valley Groundwater Flow System (coincidental with permitting of the repository, if that results). Should this occur, we are alarmed that the benefit of a basic long-term baseline for continuing to understand environmental effects will be lost. We firmly believe the model studies not only should be maintained, but expanded to include several transient model analyses to enhance our knowledge of the regional groundwater flow system.

Response
DOE believes that a comprehensive steady-state model of the Death Valley regional groundwater flow system is necessary to understand and describe the hydrologic flow system at Yucca Mountain, as part of the repository licensing process. DOE also is aware of the benefits and desired uses of a transient regional groundwater flow model. DOE has supported the development of the steady-state model for use in the License Application, and supports the continued development of the transient model for use in the future.

7.5.3.2 (7296)
Comment - EIS001683 / 0003
There are so many reasons why nuclear waste should not be stored at Yucca Mountain. Groundwater travel time at Yucca Mountain is so short that the site cannot be considered.

Response
Extensive studies show that infiltration and percolation rates at Yucca Mountain are very low, groundwater-residence times are very long, and the waste emplacement horizon has been hydrologically stable for long periods.

DOE's original 1984 site suitability guidelines (10 CFR Part 960) have been superseded by Yucca Mountain-specific guidelines (10 CFR Part 963) promulgated by DOE in 2001. Even though 10 CFR Part 960 no longer applies to Yucca Mountain, DOE believes that information and analyses do not support a finding that the site would have been disqualified under the groundwater travel time disqualifying condition at 10 CFR 960.4-2-1(d). Under that condition, a site would be disqualified if the expected groundwater travel time from the disturbed zone (the area in which properties would change from construction or heat) to the accessible environment would be less than 1,000 years along any pathway of likely and significant radionuclide travel. The definition of groundwater travel time in 10 CFR 960.2 specifies that the calculation of travel time is to be based on the average groundwater flux (rate of groundwater flow) as a summation of travel times for groundwater flow in discrete segments of the system. (In this case, the geologic and hydrologic subunits comprising the unsaturated and saturated zones.) As a practical matter, this definition provides for the consideration of the rate at which most of the water moves through the natural system to the accessible environment.

As part of its site characterization activities, DOE has undertaken various studies to identify and consider characteristics of the unsaturated (above water table) and saturated (water table) zones, such as the flow of water and transport of radionuclides, that are relevant to analyzing groundwater travel times. DOE also has considered physical evidence such as the chemistries and ages of water samples from these zones. Because of the inherent uncertainties in understanding such natural processes as groundwater flow, DOE has developed numerical models to represent an approximation of these processes and to bound the associated uncertainties.

Based on these models, which incorporate the results of these studies and available corroborating physical evidence, DOE estimates that the median groundwater travel times would be about 8,000 years, and average groundwater travel times would be longer. These models indicate that small amounts of water potentially moving in "fast paths" from the repository to the accessible environment could do so in fewer than 1,000 years. However, the models and corroborating physical evidence indicate that most water would take more than 1,000 years to reach the accessible environment. Given this, DOE believes that the site would not have been disqualified under the groundwater travel condition at 10 CFR 960.4-2-1.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

7.5.3.2 (7306)
Comment - EIS001653 / 0041
Groundwater section [3.1.4.2] needs a figure showing all springs in the area and a discussion of the relationship of the springs to the various aquifers, if any. There is also a need to describe baseline information on water chemistry in the region of influence.

Response
DOE believes that Section 3.1.4 of the EIS adequately describes the major springs in the region of influence and, although not shown specifically on figures, their general locations. The area of primary interest is the pathway that groundwater travels from beneath Yucca Mountain. As described in Section 3.1.4.2.1, this pathway is to Jackass Flats, to Amargosa Desert, and then to Death Valley. Section 3.1.4.2.2 describes the aquifers involved in this flowpath. The primary point of discharge along this path is Franklin Lake Playa in Alkali Flat, although some of the

flow from the Amargosa Desert might go to the Furnace Creek area of Death Valley. Figures 3-15 and 3-20 both show Alkali Flat and Furnace Creek. There are no other major springs or seeps along the pathway from Yucca Mountain.

The EIS mentions other well-known springs in the region, even though they are not in the groundwater pathway from Yucca Mountain. The most significant are in the Ash Meadows area. Section 3.1.4.2.1 describes these springs and Figures 3-15 and 3-20 show the location of Ash Meadows. In addition, the Saturated Zone Groundwater Quality discussion in Section 3.1.4.2.2 identifies two of the sampling points as springs in the Ash Meadows area. These springs are listed in Table 3-19 and shown in Figure 3-20 of the EIS.

The EIS contains several discussions of groundwater chemistry and quality. Section 3.1.4.2.1 discusses groundwater quality with regard to Drinking Water Standards established by the Environmental Protection Agency. Section 3.1.4.2.2 summarizes groundwater chemistry in the volcanic and carbonate aquifers in the saturated zone (Table 3-17) and the results of groundwater sampling and analysis for radioactivity (Table 3-18). This information establishes a baseline of groundwater quality and characteristics.

7.5.3.2 (7349)
<u>Comment</u> - EIS001957 / 0008
The proposed waste repository site is located in a volcanic rock sequence directly overlying carbonate rocks that comprise a regionally significant, deep Carbonate Rock Aquifer, and is also contained in the Death Valley Ground-Water Flow System. These are both known to discharge at Death Valley National Park. Ground-water discharge at park springs is the sole source of water for critical park water and water related resources and provides domestic water resources for park visitors and staff, the Furnace Creek Resort complex, state and county staff, and Tribal groups and areas.

The draft EIS inadequately addresses radionuclides leaking from the proposed repository, which will migrate to the water table and contaminate regional ground-water flow systems that ultimately discharge at springs in Death Valley National Park and at Devils Hole. The NPS [National Park Service] is mandated to protect resources entrusted to its care in perpetuity. Dangerous levels of radiation may exist long after the predicted 10,000-year life of the repository.

For example, Neptunium-237, which constitutes an important human health risk, is listed as a constituent of the waste packages that are planned to be disposed of in the Yucca Mountain repository. Neptunium-237 has a half-life of 2.1 million years. Leakages involving this element alone could result in serious contamination of park water resources.

<u>Response</u>
DOE disagrees with the National Park Service's contention that the EIS provided an inadequate evaluation of radionuclide migration in groundwater or that "dangerous levels of radiation" would exist long after 10,000 years. The calculations that the Department used to estimate the impacts described in Chapter 5 of the EIS are comprehensive. The analysis indicated that the predicted long-term levels of radioactive concentrations in groundwater and the resulting dose levels would be low, not "dangerous."

The long-term performance assessment calculations in Chapter 5 include neptunium-237. As the comment says, this is the most significant radionuclide, in terms of dose, in the 10,000- to 1-million-year period. Expected human health impacts in Chapter 5 (which include the contribution to dose from neptunium-237) for the first million years after repository closure would decline with distance from the repository (for example, see Section 5.4.2). Chapter 3 acknowledges that a small amount of groundwater might move beyond the primary groundwater discharge point at Alkali Flat (Franklin Lake Playa) to discharge in the Furnace Creek area of Death Valley. Even if this was the case, impacts in the Furnace Creek area would be less than the low impacts described in Chapter 5 for Franklin Lake Playa because impacts would decline with distance from the repository.

DOE is cooperating with the National Park Service and other Federal, state, and local agencies in a continuing effort to improve the regional groundwater modeling that supports the activities of these agencies as well as the Yucca Mountain performance assessments. This work is comprehensive, and has led to important refinements in modeling the regional groundwater system. However, nothing in this work has produced any change in the basic understanding of the regional groundwater flow regime.

7.5.3.2 (7353)
Comment - EIS001957 / 0010
Conclusions presented in the draft EIS and state of knowledge concerning the groundwater flow system are based on prevailing hydrologic conditions affecting the operation of the regional flow system. Additional transient modeling studies employing logical and predictable changes to significant parameters affecting the model outcome are necessary to determine the response of the flow system to continued development and increased groundwater withdrawals.

Such analyses utilizing variations in precipitation and groundwater recharge are essential to achieve anything approaching a reasonable understanding of response the flow system will have to those changes. Absent that data no reasonable conclusions can be derived concerning potential impacts associated with groundwater movement in the area of Yucca Mountain and the proposed repository. The NPS [National Park Service] recommends that conservation planning concluded thus far be modified to include the logical and necessary completion of these absolutely essential groundwater studies through full analysis via transient model studies.

Response
DOE (at both Yucca Mountain and the Nevada Test Site) has been supporting the development of a comprehensive regional flow model of the Death Valley groundwater system in cooperation with the U.S. Geological Survey, the National Park Service, Nye County, Inyo County, the U. S. Fish & Wildlife Service, and other entities for the last several years. Development of an updated, comprehensive steady-state model is nearing completion. The development of model capabilities to perform transient analyses on various aspects of the flow system has long been a desired objective. As long as the required level of funding is available, the Department's intent is to continue development on the regional model to achieve this capability (see Section 3.1.4.2.2 for more information).

7.5.3.2 (7396)
Comment - EIS001957 / 0018
Section 3.1.4.2.1 Groundwater, Regional Groundwater -- This section states:

"DOE has collected groundwater–level data from wells at Yucca Mountain and in neighboring areas on a routine basis since 1983, and has used the levels to which water rises in wells—called the potentiometric surface—to map the slope of the groundwater surface and to determine the direction of flow. Based on these and other data, groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley (Figure 3-13)."

However, Figure 3-13 (p.3-38), which is modified from D'Agnese, et al., shows a question mark on the groundwater flow arrow from the Amargosa Desert area towards Death Valley NP [National Park]. Figure 32 in the referenced D'Agnese, et al. report (1997) is essentially identical to Figure 3-13 in the draft EIS, except that D'Agnese's Figure 32 does not have the question mark on the subject groundwater flow arrow.

Further, Figure 27 (p.60), in this same D'Agnese, et al. report, clearly shows, as the statement from the draft EIS above indicates, that the potentiometric surface indicates that the direction of flow in the regional ground-water flow system is from the Yucca Mountain area toward the Furnace Creek Wash area in particular, and to Death Valley NP [National Park] in general. This evidence of groundwater flow from the Yucca Mountain to the Furnace Creek Wash in Death Valley NP [National Park] is corroborated by other potentiometric-surface maps and ground-water flow direction maps published by other scientists, including: Thomas and others (1986), Plates 1 and 2; Harrill and others (1988), Plate 2; Dettinger, (1989), Figure 6; Dettinger and others (1991), Plate 2; Laczniak and others (1996), Plate 1; and Harrill and Prudic (1998), Figure 14.

Response
DOE has added a figure to Chapter 3 of the Final EIS to show the estimated potentiometric surface of the Death Valley region. As noted in the legend to Figure 3-13 in the Draft EIS, the question mark on the figure indicated uncertainty concerning a component of the groundwater flow path from the Amargosa Desert to the Furnace Creek area. To avoid confusion, DOE has removed the question mark and the legend note from the figure.

The natural discharge point for groundwater from beneath Yucca Mountain is Franklin Lake Playa. A small amount of groundwater might flow through fractures in the relatively impermeable rocks in the Funeral Mountains toward discharge points in Death Valley.

7.5.3.2 (7399)
Comment - EIS001957 / 0019
Figure 29 [of D'Agnese et al. 1997], "The three subregions of the Death Valley regional ground-water flow system that encompass the area modeled in the study" of the D'Agnese, et al., report indicates that there is ground-water flow out of the Central Death Valley Subregion into the Southern Death Valley Subregion, and thence northwestward into Death Valley NP [National Park], along the path of the Amargosa River; presumably in the alluvial aquifer of the Amargosa River drainage. This ground-water pathway for the migration of nuclear contamination is not considered in the draft EIS, which is a significant omission handicapping the adequacy of the preliminary environmental impact analysis with respect to environmental consequences within Death Valley NP.

Response
Section 3.1.4.2.1 of the EIS indicates that the primary discharge point for groundwater flowing beneath Yucca Mountain is Alkali Flat (Franklin Lake Playa) to the south (through the Amargosa Desert), but recognizes that some groundwater reaching this far might bypass the playa. The general path of the water that percolates through Yucca Mountain is south toward Amargosa Valley, into and through the area around Death Valley Junction in the lower Amargosa Desert. Groundwater from beneath Yucca Mountain would merge and mix with underflow from Fortymile Wash and then flow and mix into the very large groundwater reservoir in the Amargosa Desert, where it would move slowly due to the high effective porosity of basin deposits. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume might flow south toward Tecopa in the Southern Death Valley subregion. In addition, a fraction of the groundwater might flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains toward spring discharge points in the Furnace Creek area of Death Valley.

Several large springs (Texas, Travertine, and Nevares) in the Furnace Creek Wash area of Death Valley discharge about 3,250 acre-feet (4 million cubic meters) per year near Furnace Creek Ranch on the east side of Death Valley. This spring flow exceeds the potential local recharge, and the water from beneath the Amargosa Desert contributes to the flow.

Sparse potentiometric data indicate that a divide could exist in the Funeral Mountains between the Amargosa Desert and Death Valley. Such a divide would limit discharge from the shallow flow system, but would not necessarily affect the deeper carbonate flow system that could contribute discharge to the Furnace Creek area (DIRS 100465-Luckey et al. 1996). Geochemical, isotopic, and temperature data indicate that water discharging from springs in the Furnace Creek area is a mixture of water from basin-fill aquifers in the northwestern Amargosa Desert and the deeper flow in the regional carbonate aquifer (DIRS 101167-Winograd and Thordarson, 1975). The groundwater in the northwestern part of the Amargosa Desert originates in the Amargosa River drainage in Oasis Valley and from the eastern slope of the Funeral Mountains, both of which are west of the flow paths that extend south from Yucca Mountain. Even if part of the flow from Yucca Mountain mixed into the carbonate pathway that supplies the Furnace Creek springs, it would be too little to affect the springflow chemistry noticeably. Considering the small fraction of water that would infiltrate though the repository footprint (approximately 0.2 percent or less) compared to the total amount of water flowing through the basin and the large distances involved [more than 60 kilometers (37 miles) from the source], any component from Yucca Mountain in this very long and complicated flow path would be diluted to such an extent that it would be undetectable.

Chapter 5 of the EIS does not specifically address impacts that could occur in Death Valley National Park from consumption of groundwater that flowed beneath the proposed repository. However, Chapter 5 clearly indicates that impacts would decrease with increased distance from the repository site. The assessment of long-term repository performance shows that the combination of natural and engineered barriers at the site would keep the doses resulting from releases of radionuclides well below the regulatory limits established by the Environmental Protection Agency in 40 CFR Part 197 and would keep any release small enough to pose no significant impact on the health and safety of people or the environment. If a small fraction of the water that percolated through the repository footprint flowed into the Furnace Creek area in Death Valley, the mean peak dose would be less than the dose calculated for Franklin Lake Playa. Sections 3.1.4.2.1, 3.1.4.2.2, and 5.4 of the EIS contain additional information.

7.5.3.2 (7400)
Comment - EIS001957 / 0020
Section 3.1.4.2.2 Groundwater at Yucca Mountain, Hydrologic Properties of Rock -- This section provides an overview of the hydrologic properties of various types of rock including their transmissivity and hydraulic conductivity. The discussion leads the reader to conclude groundwater moves extremely slowly in the area of Yucca Mountain; and leaves the reader to conclude little impact may arise from the relative movement of groundwater.

Dettinger in his 1989 report (p.16) states:

"Some zones within the central corridor (of the Regional Carbonate Aquifer) are highly transmissive, as indicated by large spring discharges that are fed by parts of the aquifers having imperceptibly sloping water tables, and by geologic mapping of ancestral flow paths. The highly transmissive zones may act as large-scale drains, collecting water from adjacent, less transmissive rock that underlies most of the study area."

He goes on to state:

"Results from tests of carbonate-rock aquifers throughout eastern and southern Nevada indicate that within 10 miles of regional springs, aquifers are an average 25 times more transmissive than they are further away."

The springs at Ash Meadows and Death Valley are high volume, constant discharge springs known to be supported by the regional aquifers. If Dettinger's observations are correct, then the areas surrounding them are typified by accelerated groundwater transmissivities. This occurrence is further supported by the recent discovery of subterranean amphipods being discharged from the groundwater aquifers at Death Valley. The presence of these organisms necessitates the occurrence of open space fractures or voids at some considerable distance from the springs. These fractures would result in enhanced groundwater flow.

These data indicate the rapid movement of groundwater surrounding the springs. If that area is of the magnitude theorized by Dettinger, any contamination originating at the Yucca Mountain site would be rapidly transported to Death Valley NP [National Park] and Ash Meadows springs. The environmental consequences of such an occurrence are not discussed in the draft EIS.

Response
DOE has conducted an extensive site characterization program to evaluate the proposed repository at Yucca Mountain. The general path of the water that percolates through Yucca Mountain is south toward the Amargosa Valley, into and through the area around Death Valley Junction in the lower Amargosa Valley. Groundwater from beneath Yucca Mountain would merge and mix with underflow from Fortymile Wash and then flow and mix into the very large groundwater reservoir in the Amargosa Desert, where it would move slowly due to the high effective porosity of basin deposits. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume might flow south toward Tecopa in the Southern Death Valley subregion. In addition, a fraction of the groundwater might flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains toward spring discharge points in the Furnace Creek area of Death Valley.

Sparse potentiometric data indicate that a divide could exist in the Funeral Mountains between the Amargosa Desert and Death Valley. Such a divide would limit discharge from the shallow flow system, but would not necessarily affect the deeper carbonate flow system that could contribute discharge to the Furnace Creek area (DIRS 100465-Luckey et al. 1996). Geochemical, isotopic, and temperature data indicate that water discharging from springs in the Furnace Creek area is a mixture of water from basin-fill aquifers in the northwestern Amargosa Desert and the deeper flow in the regional carbonate aquifer (DIRS 101167-Winograd and Thordarson 1975). The groundwater in the northwestern part of the Amargosa Desert originates in the Amargosa River drainage in Oasis Valley and from the eastern slope of the Funeral Mountains, both of which are west of the flow paths that extend south from Yucca Mountain. Even if part of the flow from Yucca Mountain mixed into the carbonate pathway that supplies the Furnace Creek springs, it would be too little to affect the springflow chemistry noticeably. Considering the small fraction of water that would infiltrate though the repository footprint (approximately 0.2 percent or less) compared to the total amount of water flowing through the basin and the large distances involved [more than 60 kilometers (37 miles) from the source], any component from Yucca Mountain in this very long and complicated flow path would be diluted to such an extent that it would be undetectable.

The Dettinger (DIRS 105384-1989) report mentioned in the comment focuses on flow in the carbonate aquifer system. As discussed in Section 3.1.4.2.2 of the EIS, groundwater beneath the repository is in the upper portion of the volcanic aquifer and the alluvial aquifer systems; it is confined from interaction with the lower carbonate aquifer, which is deep below Yucca Mountain. The solution cavities discussed by Dettinger (1989) are only in the lower carbonate aquifer and the velocity changes are limited to this aquifer. These solution cavities are unlikely to affect flow in the volcanic and alluvial aquifers.

The assessment of long-term repository performance shows that the combination of natural and engineered barriers at the site would keep the doses resulting from releases of radionuclides well below the regulatory limits established by the Environmental Protection Agency in 40 CFR Part 197 and would keep any release small enough to pose no significant impact on the health and safety of people or the environment. If a small fraction of the water that percolated through the repository footprint flowed into the Furnace Creek area in Death Valley, the mean peak dose would be less than the dose calculated for Franklin Lake Playa. Sections 3.1.4.2.1, 3.1.4.2.2, and 5.4 of the EIS contain additional information.

7.5.3.2 (7439)
Comment - EIS001969 / 0002
The NWPA requires DOE to provide reasonable assurance that the environment will be protected from the hazards posed by the Yucca Mountain repository. In order to meet this requirement, DOE has conducted numerous detailed analyses of Yucca Mountain's geology and hydrology for the past 15 years. Through these and other activities associated with site characterization, DOE has amassed a large body of evidence to support the likely determination that Yucca Mountain is the most suitable site to store the nation's high-level nuclear waste. Despite the fact that the most advanced technology is being utilized to design a foolproof waste barrier system for the repository and given the fact that the waste would remain radioactive for many thousands of years, we continue to be concerned that a facility of this nature inherently poses some degree of risk to wildlife resources. Our primary concerns are as follows:

Groundwater flows in aquifers below Yucca Mountain are generally to the south. Therefore, radionuclides and toxic chemicals, if introduced to the groundwater either by a short-term catastrophic event (e.g., earthquake, flood) or through long-term (i.e., more than 1,000 years) degradation of the waste storage containers, could eventually migrate to environmentally sensitive areas such as Ash Meadows NWR [National Wildlife Refuge]. A recent study found that the plutonium compound PuO_2, once thought to be the most stable form of plutonium waste, can be oxidized by water making it more soluble and increasing the risk of groundwater contamination from storage facilities (Haschke et al. 2000).

We find these and other uncertainties with containment of high level radioactive waste to be cause for concern.

Response
DOE believes that the comments expressed by the U.S. Fish and Wildlife Service concerning risks to wildlife resources are addressed in the EIS. Section 4.1.8 of the EIS discusses the potential for catastrophic events (including earthquakes) occurring at the Yucca Mountain Repository during construction, operation and monitoring, and closure of the repository, and the consequences of these events. As described in Section 4.1.3, flooding would be unlikely to release contaminants because the design of critical surface facilities would withstand the most severe reasonably possible floods. Chapter 5 discusses impacts from the long-term performance of the repository. The evaluations included impacts from volcanic (Section 5.7.2) and seismic disturbances, as well as impacts from the slow degradation of waste packages over thousands of years. This slow degradation has the highest potential to spread contaminants as they are leached into the groundwater beneath Yucca Mountain.

Section 3.1.4.2.1 of the EIS shows that the flow path of groundwater from Yucca Mountain extends to Jackass Flats and the Amargosa Desert, and continues southward to the primary point of discharge at Franklin Lake Playa in Alkali Flat. The EIS recognizes that some groundwater reaching this far might bypass Franklin Lake Playa and continue into Death Valley. The EIS also recognizes that a fraction of the groundwater that reaches the Amargosa Desert might flow through the southeastern end of the Funeral Mountains to springs in the Furnace Creek Wash in Death Valley National Park. The springs in Ash Meadows (including Devils Hole) are not along the groundwater flow path from Yucca Mountain. As described in Section 3.1.4.2.1, groundwater beneath Yucca Mountain flows to the Amargosa Desert but does not discharge in Ash Meadows. From Ash Meadows to the low axis (Carson Slough) of the Amargosa Desert, the groundwater table declines about 64 meters (210 feet), indicating that the groundwater flows from Ash Meadows toward the Amargosa Desert, not the other way around.

Chapter 5 of the EIS does not specifically address the risks to people and natural resources in Death Valley National Park from the use and consumption of groundwater. However, it clearly indicates that risks would decrease with increased distance from the repository. Accordingly, impacts to the Park, because it is far from Yucca Mountain, would be negligible.

In Section 5.3 of the EIS, DOE concluded that the predicted long-term levels of radionuclide concentrations in groundwater and the resulting dose levels at the predicted discharge area in Amargosa Valley would be low. As a consequence, DOE does not expect that the dose rates to plants and animals would cause measurable detrimental effects in populations of any species because the rates would be less than 100 millirad per day. The International Atomic Energy Agency concluded that chronic dose rates of much less than 100 millirad per day are unlikely to cause measurable detrimental effects in populations of even the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992). The DOE interim technical standard, *A Graded Approach for Evaluating Dose to Aquatic and Terrestrial Biota*, which the Department made available for interim use on July 20, 2000, contains more information about potential effects of radiation on biota.

The comment also refers to a recent laboratory finding that a species of plutonium oxide has a higher solubility than the species most often considered to be the normal oxidized form of the metal (plutonium dioxide) (DIRS 150367-Haschke, Allen, and Morales 2000). Scientists working on the Yucca Mountain Project are aware of this finding. DOE believes that the finding is within the range of conservatisms built into the plutonium solubility model used to model the long-term performance of the repository.

7.5.3.2 (7578)
Comment - EIS001969 / 0034
Page 3-36, Section 3.1.4.2.1 Regional Groundwater.

There is insufficient data to fully characterize the site-scale hydrology of the area. Because of the complexity of the geology and inconsistencies between the Large Hydraulic Gradient and thermal data, additional boreholes, appropriately configured, that penetrate to the Paleozoic carbonates beneath the Tertiary tuffs should be considered.

There is a lack of data on the hydrologic interaction between the Tertiary tufts and the underlying Paleozoic carbonate aquifers.

Response
DOE, in cooperation with Nye County, has initiated a program (called the Early Warning Drilling Program) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain, as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the ongoing site characterization program and from the performance confirmation program (if Yucca Mountain is approved for a repository), would be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information (see Section 3.1.4.2.1 of the Final EIS).

7.5.3.2 (7581)
Comment - EIS001969 / 0035
Page 3-39 and Page 3-51, Section 3.1.4.2 Groundwater.

The range of infiltration rates, hydraulic conductivities, etc. should be used rather than the average, especially in the case where the range is large. For example, apparent hydraulic conductivities range over 3 orders of magnitude (page 3-5 1). Also, the average infiltration rate of 6.5 mm/yr [millimeter per year] on page 3-39 is misleading because fracture systems allow much more rapid flow locally. The difficulty of Yucca Mountain hydrology is in the inability to predict which fractures or faults will act as highly transmissive zones. Care must be taken to show ranges of behavior so that best and worst case scenarios can both be evaluated.

Response
The EIS describes why the quantity of water moving through the proposed repository would be small compared to other sources of recharge in the region and to the amount of groundwater moving through the area. DOE believes that presenting ranges of infiltration rates in this case would add unnecessary complexity. More information, including temporal and spatial ranges of net infiltration, is in the Water Source and Movement discussion in Section 3.1.4.2.2 of the EIS.

DOE disagrees that description of an average net infiltration over the area of the repository is misleading. (It should be noted that the EIS now presents a different infiltration estimate due to the results of an updated infiltration study.) The EIS also considers smaller areas of higher and lower infiltration. Section 3.1.4.2.2 identifies infiltration rates over an order of magnitude higher in areas where thin alluvium overlies highly permeable rock. It would be misleading to imply that these higher infiltration rates occur over large areas.

DOE agrees that it is difficult to predict which fractures or faults would act as highly transmissive zones. However, much has been learned from studies, particularly chlorine-36 studies, that have suggested a correlation between subsurface locations where there is evidence of “fast pathways” (less than 50 years) and physical conditions in the mountain and on the surface. The Water Source and Movement discussion in Section 3.1.4.2.2 describes these correlations.

7.5.3.2 (7733)
Comment - EIS000817 / 0023
You also need to know how much water you are going to need for any of these operations -- for decontamination, etc. Your evaluation shows that demands (along with Nevada Test Site activities) would exceed lowest perennial yield estimates under the low thermal load for packaging scenarios. What about in retrieval? And have you evaluated how pumping that water out of the local supply affects that geological formation? Say you really deplete most of it, can areas of the aquifer dry out and cave in? Will air movement replace areas where water flowed before? What effect would this have on emissions and doses? Everything you could possibly have to do at the repository will affect everything else. You need to examine the scenarios of the unexpected and cask handling so far shows that the unexpected happens frequently. The track record is bad.

Response
Section 4.1.3.3 of the EIS discusses projected water needs for the repository. Table 4-11 lists the estimated annual water demand for each phase of the project (construction, operation and monitoring, and closure). These estimates include all the project’s water needs and include water for the decontamination of surface facilities, which is part of the monitoring period.

Section 4.2.1.2.3.2 of the EIS discusses impacts to groundwater if DOE undertook a retrieval action. The peak annual water demand for the retrieval option would be much less than the demand forecasted for the repository’s operational period when the emplacement of waste packages and the simultaneous development of new drifts would occur. (This would be the period with the highest annual water demand listed in Table 4-10.)

Land subsidence can accompany large withdrawals of groundwater that lower the water table. Where subsidence occurs, it is usually associated with fine-grained sediments, particularly silts and clays. Land subsidence above volcanic-rock aquifers, from which the repository would withdraw water, is not expected. In addition, significant lowering of the water table would require that substantial amounts of groundwater be pumped at a rate greater than the recharge rate. DOE compared water demands to the perennial yield of the area, and demonstrated that this would not occur. That is, there is no reason to believe that water demands for the repository would deplete the aquifer.

Chapter 5 of the EIS addresses the long-term performance of the repository, and includes estimates of doses from the slow release of radiological contaminants to both the atmosphere and groundwater. As indicated in Section 5.5, the repository rock is porous and allows gas to flow, establishing the need to evaluate the release of radionuclides with the potential for gas transport. As suggested by this comment, a temporary localized lowering of the groundwater table from pumping could aid air movement by causing air to move in as water moved out of an area. However, air movement in the rock is also driven by normal changes in barometric pressure caused by weather fronts moving in and out of the region.

With respect to the comment's concern for unexpected scenarios, the Yucca Mountain Project includes a major effort to identify, develop, and evaluate disruptive-event scenarios that could affect long-term repository performance. Section 5.7 of the EIS summarizes the results of this effort, and the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) contains a more detailed description.

7.5.3.2 (7854)
Comment - EIS001653 / 0037
Pg. 3-52 and Pg. 3-53 needs a figure showing ground water flow directions, depths, and aquifers. A figure should also show other groundwater wells used in the area.

Response
The Final EIS includes additional figures to support the groundwater hydrology discussions in Sections 3.1.4.2.1 and 3.1.4.2.2. A potentiometric surface map has been added that shows groundwater elevations of the Death Valley region. A figure has also been added showing a generalized hydrogeologic cross-section from Yucca Mountain to the northern portion of the Amargosa Desert. This figure shows a simplified representation of the groundwater level, aquifers, and confining units in this area.

A figure showing additional groundwater wells has not been included in the Final EIS. The current figure of well locations (Figure 3-17 of the EIS) depicts the primary wells as discussed, and DOE believes that it adequately represents the size of the area covered by monitoring and investigation wells. It is also recognized that it does not represent the number of wells in the area. It does not show all of the wells installed and monitored as part of the Yucca Mountain characterization work and it certainly does not show all of the water-extraction wells in the Amargosa Desert. A new figure showing more wells in Figure 3-17 would simply be too busy and would not add significant information.

7.5.3.2 (7861)
Comment - EIS001653 / 0040
Groundwater section [3.1.4.2] needs a map showing different aquifer systems in the region of influence.

Response
DOE agrees with the commenter. Section 3.1.4.2 of the Final EIS includes a simplified hydrogeologic cross-section from the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000). This figure shows a generalized representation of the relative positions of the volcanic, lower carbonate, and alluvium (or valley/basin-fill) aquifers in the area between Yucca Mountain and the Amargosa Desert. Figure 9.3-1 of the *Yucca Mountain Site Description* contains a more detailed hydrogeologic cross section across the Yucca Mountain site.

7.5.3.2 (8169)
Comment - EIS000817 / 0087
The "perched water" does not sound good. Have you ever watched water come out of a spring? We have a piece of land in a valley full of springs. I often watch the water flow down the valley sides and streamlets and springs and rockfall areas, and bluff areas uncovered, and think about how and where the water is going inside the rocky valley walls. You can picture it in your mind -- those fractures and faults and cavities holding the runoff until it comes out below. And it's obvious that over time, small passages become larger and fractures connect to form continuous pathways. The few tests you do now, and the limited sampling, can in no way predict when those passages will

connect in the future. Continuous pathways will lead to disaster eventually and you do not know when this will happen.

Response
The discovery and investigation of perched water bodies beneath the proposed repository horizon has provided a great deal of information on the movement of water in the unsaturated zone at Yucca Mountain. Data from these analyses represent primary pieces of evidence indicating faults and fractures in the rock that provide a relatively fast path for the vertical movement of some infiltrating water compared to the rate by which water travels through the rock matrix. Section 3.1.4.2.2 of the EIS discusses carbon-14 dating of the perched water, which indicates its age to be several thousand years. Water movement through the unsaturated zone probably is episodic, and very slow in the dry climate of the Yucca Mountain site in comparison to flowing surface water.

7.5.3.2 (8198)
Comment - EIS000817 / 0092
You think groundwater will dilute the radioactive waste in the end -- but will it? Is "dilution the solution"? Often not -- it causes more problems.

Response
DOE is not advocating dilution as the solution to managing spent nuclear fuel and high-level radioactive waste. However, the Department has to predict what would happen to these materials during the thousands of years following placement in a repository, during which its radiological hazards would still be of concern. The long-term performance of the repository described in Chapter 5 of the EIS is based on the premise that it is not reasonable to assume that the waste would stay contained and isolated forever. DOE believes it is reasonable that some dilution would occur as this material slowly entered the natural environment. The logic behind this belief is as follows: The presence of water, dripping or seeping on the waste packages, would be the most important factor controlling the longevity of the waste package. Even if packages were breached through other mechanisms, such as rockfalls, water would have to be present to carry contaminants any distance from the package. (The air pathway is of concern for the few radionuclides that might be available for gas transport, but the analysis shows this pathway to be of minor importance.) The contaminants would have to be soluble or in very small particles to move with the small-quantity, low-velocity water migrating through the unsaturated zone. As long as there was a saturated zone to receive the water moving down through the unsaturated zone, some mixing would occur when they joined, and there would be more opportunity for mixing the farther the water traveled in the saturated zone. Each of these steps involves the contaminants becoming part of a larger mass or volume of water (that is, dilution).

7.5.3.2 (8392)
Comment - EIS001023 / 0005
In its Draft Environmental Impact Statement, the Department of Energy admits that there could be low levels of contamination in the ground water in the Amargosa Desert for a long period. Do they mean for 10,000 years? The data presented by the Department of Energy in their 1998 "Viability Assessment" shows that water moves quickly through the rocks at Yucca Mountain. As a result when the containers begin to fail, radioactivity will also move quickly to contaminate the ground water in the region through the same fractures in the rock which allow carbon-14 to escape.

Response
Extensive studies at Yucca Mountain show evidence of low rates of infiltration and percolation, long groundwater-residence times, and a repository horizon that has been hydrologically stable for long periods. The proposed repository emplacement areas would be away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release.

Ongoing hydrogeochemical studies suggest that groundwater travel times for contaminants from the repository to the accessible environment (specified in 40 CFR Part 197) would be thousands to tens of thousands of years. The natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, more than 60 kilometers (37 miles) away, and travel times would be even longer.

After closure of the repository, there would be limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. DOE analyzed the potential for gas transport of carbon-14 because the repository host rocks are porous. Modeling analyses show negligible human health impacts due to releases of gas-phase carbon-14. Section 5.5 of the EIS contains more information on atmospheric radiological consequences.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

The EIS addresses long-term performance of the repository for both the 10,000-year regulatory period and for 1 million years. Results reported in the EIS are based on a state-of-the-art modeling technique that is internationally recognized as an adequate and proper approach. These results, as described in Chapter 5 of the EIS, indicate that impacts would be minor and that health effects would be thousands of times less than natural incidences of health problems in the population. Sections 3.1.4.2.1 and 5.4 contain more information.

7.5.3.2 (8410)
Comment - EIS000817 / 0126
P. 5-14. You say radionuclides would be more dispersed and the concentration of the nuclides in any volume of water would decrease. That is a big question, though. I wonder how concentrated the water really would be that carries this finally out into the public domain. Is there a scenario where the groundwater would be so little, but enough to flow out, that the concentration would be a lot more than predicted? How do we know how diluted it will really be long-term? Groundwater and aquifers will change over time.

Response
This comment is correct in identifying dispersion as one of the key elements in the effort to project (model) how contaminants might move in the environment. There was past concern over the amount of dispersion that would occur by the time water had infiltrated to the depth of the saturated zone and again as the water moved through the saturated zone. As a result of this concern, the DOE initiated an expert elicitation process, bringing together a number of experts in the field to determine what they felt would be appropriate dispersion and factors to use in projecting impacts from the proposed repository action. As described in the paragraph following the one identified in the comment, the factors recommended by the experts were used in the long-term performance modeling efforts described in the EIS. This process is further described in Section I.4 of the Draft EIS. Use of these dilution factors represented a significant departure from earlier modeling efforts for Yucca Mountain in which effective values of dilution were typically orders of magnitude higher. It should be noted that the long-term performance analysis in the Final EIS is somewhat different than that described in the Draft EIS. The analysis has been modified to conform to new requirements specified in 40 CFR Part 197, *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada*.

7.5.3.2 (8417)
Comment - EIS000817 / 0129
P. 5-15. I do not agree that Lehman and Brown's theory of flow paths will not come into effect because of the "long lived" waste packages. Don't depend on this. Work on the theory that the packages will not last as long as expected. Be prepared for that and know what to expect in that case.

Response
The comment refers to a statement in Section 5.2.3.4 of the Draft EIS. The EIS cites Lehman and Brown (DIRS 149173-1996), who propose an alternate conceptual model of saturated flow downgradient from Yucca Mountain, which could have some unquantified effect on dose estimates at a compliance point near the community of Amargosa Valley. The EIS maintains that such effects of alternative flow modeling would be relatively small, because dose rates are much more controlled by waste package failures than by rates of flow in the saturated zone.

The commenter argues that DOE should not place reliance on the long-lived waste packages. As discussed in Draft EIS Section 5.2.3, adequate performance of the repository is based on four key attributes: (1) limited water contacting waste packages, (2) long waste package lifetimes, (3) slow release of radionuclides from waste packages, and (4) reduction in the concentration of contaminants during transport to the point of human exposure. Each of these attributes is simulated in the Total System Performance Assessment that calculates dose rates at different times in the future. DOE recognizes that a great deal of uncertainty exists in the Total System Performance Assessment process as discussed in Section 5.2.4 of the Draft EIS, and uses alternative conceptual models and probability theory to deal with uncertainty and variability as described in Section 5.2.4.3.1 of the Draft EIS. While uncertainty exists in all aspects of performance assessment, it is important to realize what types of uncertainty will most influence overall results. Assessing this relative importance, termed sensitivity analysis, is described in Section 5.2.4.3.4 of the Draft EIS. Lehman and Brown's alternative model, and its potential effect on dose rates, cannot be analyzed quantitatively because their presentation is merely a brief summary of their work and does not provide a basis for judging its validity (DIRS 149173-Lehaman and Brown 1996).

DOE believes the issues related to uncertainty of the performance of the repository are treated adequately in Section 5.2.3 of the Draft EIS.

7.5.3.2 (8418)
<u>Comment</u> - EIS000817 / 0130
I'm thinking of something from "Civil Action" (book by Jonathan Harr), something about that the flow of the contaminated water could go under the river. I found that fascinating. This Darcy's Law about the quantity of water flowing through a given area is equal to the hydraulic conductivity of the material [through] which it flows multiplied by the size of the opening, multiplied again by the gradient or angle of incline. How does this fit in with the repository site, climate changes in rainfall rate, changes in size of continuous cracks and fissures in the surrounding rock by heat from the casks making them larger and connecting them, and the pressure changes and temperature changes affecting flow directions and the incline. All this, and where does the water really go? How much? When? How could you possibly predict all this? I don't think you can. What if the runoff flowed off laterally before it got to groundwater in the saturated zone and got out in surrounding land and air? Is this at all possible? Or could it get past the groundwater somehow without being diluted and flow out? In other words, is the groundwater level beneath the repository like a lake under there? No islands or peninsulas in it? I'm trying to picture just how it is under there. Don't assume it's one big flow and covers the whole space. Ever try to drill a well by hand and not hit water where it was supposed to be? We did this summer. It's a surprise. Could this be the case at Yucca in some areas and throw all your calculations off? Computers like to deal with "idealized" situations where sameness fits the calculations to make them "work" -- but nature is full of variation and diversity, so don't expect your neat little projections to be what is really there. It probably won't be the case. Water (and gases) seek any opening of escape they can find, and water tends to make its avenues of escape larger and more continuous as it goes along over time. Don't forget that. And -- water is a thief. It takes whatever it can along with it. Don't forget that, either. Sometimes I think scientists get so involved in their intricate computer models that they forget to look at the real thing, the total picture of how all of it works together. Often studies are so segmented that nobody puts them together to see if they really work together. That has happened in cask fabrication and can happen in water flow studies.

<u>Response</u>
This comment describes some of the complex issues and problems facing DOE scientists and engineers working to model the movement of water and contaminants in the subsurface environment. The conceptual model of water flow in Section 3.1.4.2.2 of the EIS shows both lateral and vertical flow in the unsaturated zone as water moves from the ground surface to the water table. The groundwater can be viewed simplistically as a lake (or very slow moving river) sitting underground in saturated rock. There could be islands or peninsulas where the water does not flow (or moves so slowly that it cannot be easily extracted from a well) due to faults and changes in rock characteristics. These would be areas of less permeable materials rather than areas where water might slip through from above.

The long-term performance assessment of the repository, as described in Chapter 5, includes evaluations of impacts from radioactive and nonradioactive materials released to the environment during the first 10,000 years after closure. The principal means by which these materials could be exposed over time to humans and the environment include movement through the unsaturated zone and then the groundwater (saturated zone). The Yucca Mountain site characterization effort is centered around learning enough about the site to make reasonable projections on how and when contaminants would move if the repository were to be constructed.

The long-term impact projections in the EIS are based in part on forecasts involving what the future environment will be like and how natural subsurface features vary over distance. These types of forecasts are associated with some uncertainty, particularly when they must consider thousands of years and long distances. Section 5.2.4 of the EIS addresses uncertainties associated with the analysis of the repository's long-term performance. This section also addresses the possible effects that uncertainties might have on the reported impact estimates. In the summary of the uncertainty discussion, DOE describes the current results of performance assessment as a "snapshot in time" that it will continue to refine with ongoing work. The Department believes the performance results presented in the EIS are conservative estimates and that ongoing work will increase confidence in those estimates.

7.5.3.2 (8454)
Comment - EIS000817 / 0134
P. 5-23, 5.3. You describe the general direction of groundwater movement NOW. But this could change. An earthquake or seismic event could remap this whole system. You have springs, alluvial aquifers -- connections between these and pressure differences that direct the flow. This could all change if land lifts or drops and pressures change. Rocks do strange things when they crack up or fracture. You can't predict what will happen. What if the volcanic aquifer ends up flowing into the carbonate aquifer??? What happens to Ash Meadows or Devils Hole then? And the Devils Hole pupfish?

Response
DOE shares the commenter's concern that it is not possible to predict precisely what would happen after significant seismic event at Yucca Mountain. Experts have studied records of historic seismic events and geologic evidence of ancient seismic events to help understand the possible size and frequency of future seismic events at and near Yucca Mountain. DOE has also examined the impacts to the long-term performance of the repository as from seismic activity. These analyses included possible changes to groundwater flow caused by seismic events. The results indicate that there would be little change in the pattern of groundwater flow from the creation of a permeable fault (a fault zone across which water can flow) and no effects if the fault was a barrier to water flow. Section 5.7.3 of the EIS and Section 4.4.3 of the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) describe the results of these analyses.

7.5.3.2 (8606)
Comment - EIS001256 / 0006
We would expect that your reply to our hydrologic and geologic concerns will include descriptions of the engineering barriers that have been designed, the most recent of which is a system of water shields to be placed over the storage casks. This presents a fundamental problem in itself. Yucca Mountain, or whatever site selected for long term storage, was supposed to offer a stable geologic barrier to protect people and the environment from high level nuclear waste. Instead, you are designing engineering barriers to provide the required protection. Why can't these engineering barriers be built at the point of origin of the waste? Why does the nuclear waste have to be transported thousands of miles, contaminating handling materials and jeopardizing health and safety all along the transportation routes?

Response
The NWPA (Section 114(f)(2) and (3)) provides that DOE need not consider in the EIS the need for a geologic repository or alternatives to geologic disposal. In addition, the EIS does not have to consider any site other than Yucca Mountain for development as a repository. For these reasons, this EIS did not consider constructing engineered barriers at existing waste sites similar in function to those proposed for the repository.

In the *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DIRS 104832-DOE 1980), DOE evaluated alternatives to mined geologic disposal including very deep borehole disposal, disposal in a mined cavity that resulted from rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal, and no action. In a 1981 Record of Decision on that EIS, DOE decided to develop mined geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste.

7.5.3.2 (8678)
Comment - EIS001816 / 0002
Section 3.1.4 Hydrology (page 3-58): the statement about, "there is no reason to believe that radionuclides from nuclear tests could migrate as far as YM during the active life of the repository." This statement is a belief and not a fact yet. Although there is a sizeable amount of data from the NTS testing program and more being collected simultaneous to YM, the Underground Test Area (UGTA) project has not established with credibility and acceptability that radionuclide contamination would reach the repository during its active life. The Tritium Transport Modeling (1997) by DOE on Pahute Mesa gave a range of arrival times for tritium to reach the Oasis Valley area from the present date to as little as 40 years from now. Possibly with the collection of more data from the data-sparse area between YM and Pahute Mesa, the DOE UGTA program will more confidently establish tritium transport times and pathways beneath YM. The Yucca Mountain Project and Underground Test Area Subproject must cooperate m [sentence incomplete]

Response
For the last several years, DOE, in close cooperation with the U.S. Geological Survey, the National Park Service, Nye County, Inyo County, and other entities, has supported the development of a regional model of groundwater flow that combines the data acquired by the Yucca Mountain Site Characterization Project and the Nevada Test Site (NTS). DOE (DIRS 103021-1997) used very conservative assumptions to show that tritium from nuclear testing moving in the groundwater could reach the boundaries of the Nevada Test Site and Nellis Air Force Range in a matter of decades. It should be noted that the flowpaths predicted in this study do not include paths from underground testing areas, including Pahute Mesa, to Yucca Mountain. Additionally, the Nevada Test Site study concluded that the results of groundwater sampling and analysis have shown that "…the conservative assumptions used to predict transport to Oasis Valley do not appear to be likely in reality" (DIRS 103021–DOE 1997). That is, monitoring has not shown tritium to be moving as rapidly as predicted even when using the conservative assumptions of the model. As additional data become available, the model will continue to be updated to analyze a variety of groundwater issues that are relevant to the Death Valley flow system and the performance of the repository.

DOE has modified Section 3.1.4 of the EIS to identify the tritium-transport study. This study recognizes that tritium from weapons testing could travel in the groundwater to locations at or near the boundary of the Nevada Test Site in tens of years, but that the predicted flowpaths would not pass beneath Yucca Mountain.

7.5.3.2 (8744)
Comment - EIS001816 / 0012
Section 3.1.4.2.2 (page 3-49): The study of fluid inclusions by Dublyansky (1998), and the conclusion that they were caused by warm upwelling of water and not percolation downward by surface water merits more questions. What relationship does the ongoing study by Dr. Jean Cline (UNLV) have to Dublyansky's theory? Since YM is funding the investigation, the DEIS must define how and where the fluid inclusion study will be utilized as a contribution that is technically verifiable and reproducible, and that is in full transparent view of and inspection by the public.

Response
Based on the results of the analyses in Section 3.1.4.2.2 of the EIS, DOE does not believe that a credible rise of the water table would inundate the waste-emplacement areas. However, Section 3.1.4.2.2 does discuss evidence that the elevation of the water table at Yucca Mountain has fluctuated over time, due largely to changes in the climate. In addition, DOE examined the cumulative effects on the elevation of the water table from a wetter climate, earthquakes, and a volcanic eruption. Based on the evidence at hand, no reasonable combination of wetter climates, earthquakes, and volcanic eruptions could raise the elevation of the water table sufficiently to inundate the waste emplacement areas at Yucca Mountain.

Section 3.1.4.2.2 of the EIS discusses several opposing views on fluctuations in the elevation of the water table at Yucca Mountain. Some investigators believe that the water table has risen in the past to elevations that are higher than the proposed waste emplacement areas. DOE does not concur with these views, nor did an expert panel that the National Academy of Sciences convened to examine this issue specifically (as described in Section 3.1.4.2.2). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level. Although DOE disagrees with the central scientific conclusions in Dr. Dublyansky's report (DIRS 104875-1998), it continues to support research in this area, as well as on other aspects of the geology and hydrology that enhances our understanding of the site. Dr. Cline's fluid inclusion study is viewed as a supplemental confirmatory research effort.

7.5.3.2 (8807)
Comment - EIS001907 / 0029
Groundwater contamination would deliver the worst doses of radioactivity to nearby residents, and because of this water quality must be protected to the fullest extent of the law, which this proposition fails to do. Yucca Mountain must have the most stringent of standards, for leakage will only increase over time, yet these standards are being lowered.

The only bulk source of Chlorine-36 in our atmosphere is from above ground nuclear weapons tests done in the Pacific, salt in the seawater was activated which formed the radioactive chlorine isotope. Its presence at repository depth proves that water has traveled there within the past 50 years, and proves a "fast flow" path for groundwater travel. The science has shown that water moves too fast through Yucca Mt. for it to qualify under 10 CFR 960.4-2-1. Now there is an attempt to change these standards. This act of trying to change the rules in the middle of the games is shameful.

Response
Section 1.3.2.4 of the EIS explains the legislative history of the repository program and the rationale for modifying the initial regulations that were applicable to a generic repository to the new regulations that are applicable only to Yucca Mountain. As reported in Chapter 5 of the EIS, modeling of the long-term performance of the repository shows that the combination of natural and engineered barriers at Yucca Mountain would keep doses resulting from any releases of radioactive contaminants well within the regulatory limits established by 40 CFR Part 197.

As part of its site characterization program, DOE has used a variety of naturally occurring isotopic indicators, one of which is chlorine-36, to investigate the nature of infiltration and deep percolation of water at the site. Results from this program detected elevated amounts (values above normal background measurements) of "bomb-pulse" chlorine-36 in several places in the Exploratory Studies Facility from nuclear testing conducted during the 1950s and 1960s. The locations where this bomb-pulse chlorine-36 has been detected in the Exploratory Studies Facility are associated generally with known through-going faults and well-developed fracture systems close to those faults. This suggests that there are connected pathways through which surface precipitation has percolated to the repository horizon within the last 50 years. These findings, however, must be viewed in the context of whether waste can be stored safely at Yucca Mountain. Overall, most of the water that infiltrates into Yucca Mountain moves much more slowly through the matrix and fracture network of the rock. Only a small fraction has moved quickly through the connected portion of the fracture network. Carbon isotope data from water extracted from the matrix correspond to residence times as long as 10,000 years.

7.5.3.2 (8927)
Comment - EIS001922 / 0004
Hydrology of the Site

A tremendous amount of scientific uncertainty currently surrounds hydrothermal incursions of groundwater at the site. It is unclear whether flooding has previously occurred, and if it has, how recently it occurred. The DEIS makes the assumption that the repository will remain unsaturated and its estimates of how long the container packages will last are based on that assumption. If the EIS [is] incorrect regarding hydrothermal incursions and the project continues, the consequences could be astronomical in terms of groundwater contamination and damage to the public and environment. The EIS should address the potential effects of water incursion on container packages.

The groundwater at the site currently is used for agriculture. The Amargosa Valley farming community relies directly upon the groundwater from the site for its livelihood and drinking water. The DEIS does not fully address the consequences of contamination of the groundwater and its impact on regional uses. It incorrectly assumes dilution will reduce concentrations of radiation to acceptable levels. Given that the longevity of the container and the mountain barrier have not been determined, this assumption is premature at best, woefully underestimated at worst.

The alarming and potentially devastating effects of upwelling and associated surface and groundwater contamination [were] not dealt with in the DEIS and should be addressed. An upwelling of contaminated water could impact a large land area and significantly alter the pathway and the maximum individual dose assumptions.

Response
Based on the results of analyses reported in Section 3.1.4.2.2 of the EIS, DOE does not believe that the waste emplacement areas would be inundated by a credible rise of the water table. This section does discuss evidence, however, that the elevation of the water table at Yucca Mountain has fluctuated over time. These fluctuations have been due largely to changes in the climate. DOE also examined the cumulative effects on the elevation of the water table from a wetter climate, earthquakes, and a volcanic eruption. Based on the evidence at hand, no reasonable combination of wetter climates, earthquakes, and volcanic eruptions could raise the elevation of the water table sufficiently to inundate the waste emplacement areas at Yucca Mountain.

Section 3.1.4.2.2 also discusses several opposing views concerning fluctuations in the elevation of the water table at Yucca Mountain. These investigators believe that the water table at Yucca Mountain has risen in the past to elevations that are higher than the waste-emplacement areas. DOE does not concur with these opposing views, nor did an expert panel that was convened by the National Academy of Sciences to examine this issue. DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level. Because DOE believes that this scenario is not credible and therefore not significant, DOE did not evaluate the impacts of groundwater inundation of the waste emplacement areas. This approach is consistent with regulations of the Council on Environmental Quality [40 CFR Part 1501.7(a)(3)], which directs agencies to identify and eliminate from detailed study those issues which are not significant. DOE believes that Section 3.1.4.2.2 of the EIS, which discusses dilution, adequately addresses the consequences of radionuclides in the regional groundwater system. As reported in Chapter 5 of the EIS, modeling of the long-term performance of the repository shows that the combination of natural and engineered barriers at Yucca Mountain would keep such releases within the regulatory limits established at 40 CFR Part 197.

7.5.3.2 (8941)
Comment - EIS001030 / 0003
Yucca Mt. is not adequate because of geological risks. Studies of the fissures in the rocks of the area indicate that both radioactive water and gas may escape. Heat from the waste itself may generate problems. Hot water from below the site associated with volcanic activity poses a risk. The site is riddled with seismic faults. The DEIS has not dealt adequately with these risks.

Response
Extensive studies conducted at Yucca Mountain show evidence of low rates of infiltration and percolation, long groundwater-residence times, and a repository horizon that has been hydrologically stable for long periods of time. The proposed waste-emplacement areas are located in areas away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide releases.

After closure of the repository, there would be a limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. The potential for gas transport of carbon-14 was analyzed because the repository host rocks are porous. Modeling shows negligible human-health impacts due to releases of gas-phase carbon-14. See Section 5.5 of the EIS for additional information on atmospheric radiological consequences.

The heat generated by the waste packages can be managed by using various options (e.g., blending, aging, waste package spacing, and ventilation). Under the higher-temperature operating mode flexible repository design, heat generated by the waste packages may add some increased uncertainty to possible effects of the repository on the hydrologic system. The heat generated by the waste packages may, however, be beneficial by driving water away from the drift wall rock for a period of about 1,500 years.

Intensive investigations by DOE identified no evidence or credible mechanism to account for a rise in groundwater to flood the potential repository horizon in the vicinity of Yucca Mountain. Szymanski (DIRS 106963-1989) proposed that during the last 10,000 to 1,000,000 years, hot mineralized groundwater was driven to the surface by earthquakes and volcanic activities. This hypothesis goes on to suggest that similar forces could raise the regional groundwater in the future and inundate the repository horizon.

DOE requested the National Academy of Science's National Research Council (NAS/NRC) render an independent evaluation of the issue. After reviewing available information, the NAS/NRC concluded in their 1992 report that no mechanism was known that could cause a future inundation of the repository horizon. The features cited by Szymanski (DIRS 106963-1989) as proof of groundwater upwelling in and around Yucca Mountain are related to the much older (13 to 10 million years old) volcanic process that formed Yucca Mountain and the underlying volcanic rocks. Significant water table excursions (exceeding tens of meters) to the design level of the repository due to earthquakes are unlikely. As discussed in EIS Section 3.1.3.1, the likelihood of volcanic activity in the area is low (one chance in 70 million annually), and it would raise the water table a few tens of meters, at most.

DOE scientists have estimated that the water table could rise by 50 to 130 meters (160 to 430 feet) under extremely wet climatic conditions. The regional aquifer has been estimated to have been a maximum of 120 meters (390 feet) above present levels based on mineralogic data, isotopic data, discharge deposit data, and hydrologic modeling analysis. The occurrence of an earthquake under these extreme climatic conditions might cause an additional rise in the water table of less than 20 meters (66 feet), still leaving a safety margin of 20 meters (66 meters) or more between the water table and the level of the waste-emplacement drifts. The 1992 Little Skull Mountain earthquake (magnitude 5.6) raised water levels in monitoring wells at Yucca Mountain a maximum of less than 1 meter (3.3 feet) (DIRS 101276-O'Brien 1993). Water level and fluid pressure in continuously monitored wells rose sharply and then receded, over a period of several hours, to pre-earthquake levels. The water-level rise in hourly monitored wells was on the order of centimeters and indistinguishable after 2 hours (DIRS 101276-O'Brien 1993).

Dublyansky (DIRS 104875-1998) proposed another line of data in support of the warm-water upwelling hypothesis. This study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. The report concludes that some of these crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of scientists with expertise in hydrology, geology, isotope geochemistry, and climatology did not concur with the conclusions in the report (DIRS 100086-Stuckless et al. 1998). Although the DOE has disagreed with the central scientific conclusions in this report, the DOE agreed to support continuing research. An independent Investigation by Jean Cline, at the University of Nevada, Las Vegas, is scheduled for completion in 2001. See Section 3.1.4.2.2 of the EIS for additional information.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

DOE based its analysis of impacts on a state-of-the-art modeling technique that has been reviewed by many oversight groups. The results of this analysis, described in Chapter 5 of the EIS, indicate that impacts would be low and that health effects would be thousands of times less than natural incidences of health problems in the population. Sections 3.1.4.2.1 and 5.4 provide additional information.

7.5.3.2 (8944)

Comment - EIS001030 / 0004

It is clear from research at Yucca Mt. and surrounding areas that we do not have a clear understanding of underground water dynamics. Further new information from other sites on the heretofore unknown rapidity at which radioactive substances can move in groundwater makes this issue even more troubling.

Response

Ongoing hydrogeochemical studies suggest that groundwater travel times for contaminants from the repository to the accessible environment, about 18 kilometers (11 miles) away, are from thousands to tens of thousands of years. The natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, more than 60 kilometers (37 miles) away, and travel times would be even greater.

At the Benham nuclear test site on the Nevada Test Site, testing has indicated rapid transport of colloidal-associated plutonium. The results of groundwater monitoring indicate that a small fraction of plutonium has migrated 1.3 kilometer (0.8 mile) from the blast site in 30 years. In fracture systems, colloids that are repelled from the wall rock can move faster than nonsorbing dissolved species because they remain in the faster flowing portions of the flow paths. DOE has included plutonium colloidal transport in the EIS analysis, and it will be the subject of continuing work.

Analysis of long-term repository performance shows that the combination of natural barriers and engineered barriers at the Yucca Mountain site would keep such a release small enough to pose no significant impact to the health and safety of people or the environment. See EIS Sections 3.1.4.2.2 and 5.4 for more information.

7.5.3.2 (9076)
Comment - EIS001887 / 0427
The Nuclear Waste Policy Act requires that an EIS, consistent with the National Environmental Policy Act (NEPA) be prepared and accompany a recommendation for site approval. The amended NWPA (1987) still requires consistency with NEPA, but does not require the DOE to consider:

1. The need for the repository
2. Alternatives sites to Yucca Mountain, or
3. Non-geological alternatives

NWPA Section 114(f) specifically states that all other provisions of NEPA apply. NEPA Section 1502.22 relates to incomplete or unavailable information. This section was developed as a result of dropping the "Worst case analysis" from previous NEPA provisions. NEPA regulations amended in 1986 now require that if information is available that would aid in evaluating uncertain effects, it must be obtained and analyzed unless it is too expensive to do so. If costs are prohibitive, then it must be disclosed as incomplete or unavailable information. Specifically, regulations require that if information cannot be obtained, the EIS must include:

1. A statement that such information is incomplete or unavailable.

2. A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment.

3. A summary of existing credible scientific evidence which is relevant to evaluating reasonably foreseeable significant adverse impacts on the human environment.

4. The agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community.

The Yucca Mountain DEIS is not in compliance with numbers 2, 3 or 4 above. While the DOE has stated that information used in determining the groundwater flow model is incomplete or unavailable, the existing credible scientific evidence which is relevant to evaluating reasonably foreseeable significant adverse impacts has not been summarized nor has it all been utilized in developing flowpaths.

Also, the impacts evaluation assumed the same groundwater flowpaths and characteristics which were used in the DOE Viability Assessment and Total System Performance Assessment documents; i.e., a matrix type flow evaluation utilizing only 2D flow and 1D transport calculations. While these are generally accepted methods, they may not be representative of the saturated zone flow field that exists at Yucca Mountain today.

The DOE has not utilized all available and relevant data in their pathway identification or characterization. Because of this, the impacts in terms of dose to the Critical Group(s) or receptors may be misrepresented. While recognizing differing view points regarding groundwater flow, the DEIS fails to analyze flowpaths from a full data set that considers this information. Because all data that have been generated are not considered in the impacts evaluation, there may be significant differences in the groundwater impacts projected in the DEIS. Unless these analyses are considered, impacts projected in the DEIS are inadequate for NEPA compliance and their credibility questionable.

In addition, the requirement to disclose all credible scientific evidence extends to responsible opposing views provided these are supported by theoretical approaches or research methods generally accepted in the scientific community.

The Yucca Mountain DEIS recognizes differing viewpoints regarding groundwater flow (Section 3.1.4.2. and Section 5.2.3.4.) and references the State of Nevada study of Lehman and Brown, but it fails to evaluate the impacts and actually gives little credibility to this alternative flowpath model. The DEIS admits that the alternative flowpath could produce different results, however, it states the extent to which the different viewpoint would affect the impacts is unknown but speculates the effects would be minimal (due to long canister lifetimes). This may not be the case, and in terms of doses to populations of the State of Nevada, any credible alternative must be evaluated.

Response
DOE believes that the EIS is consistent with the National Environmental Policy Act, as amended (42 U.S.C. 4321 *et seq.*), and with the Nuclear Waste Policy Act, as amended (42 U.S.C. 10101 *et seq.*). DOE acknowledges in several places in the EIS that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, including incomplete or unavailable information, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

Sections 3.1.4.2.1 and 3.1.4.2.2 discuss opposing views on groundwater conditions and groundwater boundaries. Although DOE disagrees with the central scientific conclusions of these opposing views, it continues to support research in several areas and on other aspects of the geology and hydrology of the region to enhance the Department's understanding of the site.

7.5.3.2 (9213)
Comment - EIS001938 / 0002
The DEIS completely fails to address potential impacts of the Yucca Mountain storage project on the water resources of Death Valley National Park and surrounding wildlands. It is clear that the repository may still constitute a dangerous source of radiation even after its projected 10,000 year life-span. The radionuclides in the proposed waste packages have half-lives ranging from 24,000 years (Plutonium 239) to 2,100,000 years (Iodine 129). Neptunium 237, which is projected to pose a serious health threat, has a half-life of 2.1 million years. The potential of this project, over time, to destroy the ecological integrity of DVNP and other wildlands must be addressed.

The DEIS does not address the fundamental question of overall risks of contamination of groundwater or downgradient natural resources from the repository site. Should a leak occur from the proposed repository site, it will likely migrate and contaminate groundwater and springs within Death Valley National Park, the Devils Hole Detached Management Unit of DVNP, the Ash Meadows National Wildlife Refuge, designated Wilderness areas, and the many natural resources contained in these specially-designated areas.

The DEIS admits there exists significant uncertainty over the actual risk of leakage of radioactive material into the groundwater aquifer that contains the Amargosa River system and which underlies portions of DVNP. Numerous studies demonstrate that the regional groundwater flow system runs from the Yucca Mountain area toward the Furnace Creek wash area in Death Valley National Park. This obvious pathway for groundwater contamination is not adequately considered in the DEIS; in fact the DEIS flatly and unjustifiably ignores the information contained in hydrological studies other than its own. Of particular note, studies conducted by Inyo, Esmeralda and Nye Counties have established a direct connection between the aquifer underlying Yucca Mountain and surface springs in Death Valley National Park. See, e.g., “An Evaluation of the Hydrology at Yucca Mountain The Lower Carbonate Aquifer and Amargosa River” (Inyo and Esmeralda Counties 1996), and “Death Valley Springs Geochemical Investigation” (Inyo County 1998). These same studies indicate that communities in Amargosa Valley utilize groundwater that may be hydrologically contiguous to the Yucca Mountain aquifer.

Additional study will clearly be necessary to fully understand the nature of the groundwater flow system. This basic knowledge will be required to accurately determine the potential environmental impacts of the Yucca Mountain repository project. Effective modeling must also consider a response of the flow system to a number of likely variables, including continued development, increased groundwater withdrawals, variations in precipitation, and groundwater recharge. Absent that kind of data and analysis, the DEIS will not be able to conclusively determine potential environmental impacts of the proposed project, and is therefore incomplete.

The DEIS implies that groundwater moves very slowly in the Yucca Mountain area, giving the false impression that impacts to the environment from groundwater movement will be negligible. Numerous studies, however, indicate that zones in this regional aquifer are highly transmissive. The constant discharge, high volume springs at Ash Meadows and Death Valley further indicate that the area around these springs may be surrounded by accelerated groundwater transmissivities. Any contamination originating at the Yucca Mountain Site could thus quickly be transported to Death Valley and Ash Meadows contrary to the claims of the DEIS.

The DEIS also fails to assess the impacts of expected climate change over the next 10,000 years on the transport of groundwater between the repository site and Death Valley National Park. In the past 10,000 years, there have been significant climatic changes, including periods much wetter than today. Studies that have reviewed the effects of increased filtration that may result from a wetter climate (e.g., global warming, as predicted by scientists) have direct bearing on the repository proposal. A wetter climatic regime could both increase the rate of corrosion of waste canisters and speed the travel of groundwater, which would result in greater and more rapid dispersal of radionuclides to the environment.

In addition to groundwater impacts, the project also poses a very real threat to surface water resources. The document fails to consider the potential impacts from radioactive leaks from the repository manifesting in surface-water springs, or from transportation-related accidents of shipments containing high-level radioactive waste, to the surface-water resources of Death Valley National Park, Ash Meadows NWR, designated Wilderness areas, and the Amargosa River. Nor have the impacts of such contamination of surface water on the wildlife, vegetative and human communities dependent on those surface waters been adequately assessed.

Response

Section 3.1.4.2.1 of the EIS shows that the flow path of groundwater from Yucca Mountain extends to Jackass Flats and the Amargosa Desert, and continues southward to the primary point of discharge at Franklin Lake Playa in Alkali Flat. The EIS recognizes that some groundwater reaching this far might bypass Franklin Lake Playa and continue into Death Valley. The EIS also recognizes that a fraction of the groundwater that reaches the Amargosa Desert might flow through the southeastern end of the Funeral Mountains to springs in the Furnace Creek Wash in Death Valley National Park.

Chapter 5 of the EIS does not specifically address the risks to people and natural resources in Death Valley National Park from the use and consumption of groundwater. However, it clearly indicates that risks would decrease with increased distance from the repository. Accordingly, impacts to the Park, because it is far from Yucca Mountain, would be negligible.

Section 5.9 of the EIS discusses the impacts to biological resources from the long-term performance of the repository. DOE did not quantify impacts to biological resources, but related them to the negligible impacts expected to humans from the use and consumption of groundwater.

The springs in Ash Meadows (including Devils Hole) are not along the groundwater flow path from Yucca Mountain. As described in Section 3.1.4.2.1 of the EIS, groundwater beneath Yucca Mountain flows to the Amargosa Desert but does not discharge in Ash Meadows. From Ash Meadows to the low axis (Carson Slough) of the Amargosa Desert, the groundwater table declines about 64 meters (210 feet), indicating that the groundwater flows from Ash Meadows toward the Amargosa Desert, not the other way around.

The EIS acknowledges that some of the groundwater beneath Yucca Mountain might flow to Furnace Creek Wash in Death Valley National Park. DOE is not aware of any evidence to indicate that this represents the regional groundwater flow system, as the commenter suggests. The studies by Inyo, Esmeralda, and Nye Counties cited by the commenter do not make this claim. The *Death Valley Springs Geochemical Investigation* (DIRS 147808-King and Bredehoeft 1999) cites evidence that a portion of the flow from the Furnace Creek springs must originate from the area of the Amargosa Desert. Based on the evidence, the study was unable to identify a specific source. Its conclusion states, “The water can come from recharge in 1) the area of NTS [Nevada Test Site] and Yucca Mountain; or 2) the Amargosa Basin fill deposits; or 3) the area to the east that includes the Ash Meadows springs, or some combination of all three.” The study identifies the quantity of water discharging at the springs in Furnace Creek, which is smaller than the estimates of water moving through the Amargosa Desert toward the discharge area at Alkali Flat. That is, the quantity of water moving toward Furnace Creek would not be the regional groundwater flow system; rather, it would be only a portion of the regional system. Finally, the EIS identifies Amargosa Valley and other parts of Amargosa Desert to the south as being over the primary groundwater flowpath from the area of Yucca Mountain. DOE believes that the information and conclusions in the cited studies are consistent (or at least are not inconsistent) with the model of groundwater flow described in the EIS.

DOE recognizes that the acquisition of additional data would reduce the uncertainty regarding some aspects of the long-term performance of the repository. But DOE also recognizes that some uncertainty is inherent to the process. The approach used by the Department to assess the long-term performance of the repository (summarized in Chapter 5 of the EIS) was to recognize the uncertainties that are important to the assessment and to identify which of these uncertainties could be minimized with additional data and which could not. With respect to those uncertainties that are the result of a data gap, the approach was to make conservative assumptions where necessary, realizing that information gained from ongoing studies may eventually support less conservative assumptions and less conservative estimates of impacts. The approach used by DOE to account for uncertainties associated with the long-term performance of the repository is discussed more fully in Section 5.2.4 of the EIS.

In summary, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

Chapter 5 of the EIS describes how DOE modeled the movement of contaminants from the slow degradation of waste packages in the repository. The model included both the slow movement of water through the rock matrix and the relatively fast movement of water along rock fractures and faults. Although the rate at which groundwater moves is important to the model, it is not the only factor that would control the movement of contaminants. Section I.2.4 describes how DOE modeled waste package degradation and how the cladding and waste form degradation models would come into play before contaminants would actually become available for transport through the unsaturated and saturated zones. It also describes the various mechanisms that would affect how materials move through these zones, including movement with colloids and the sorption and desorption that would occur as individual radionuclides or chemicals interacted with the rock through which they were moving. These and other parameters used by DOE in the performance assessment model are conservative estimates, thereby tending to increase impacts to groundwater and downgradient users. As described above, some of the groundwater flow beneath Yucca Mountain could reach the Death Valley area (either as spring discharge in the Furnace Creek area or as underflow moving past the Alkali Flat area), but most of the flow goes no farther than Alkali Flat. The Ash Meadows area is not in this groundwater flowpath.

With respect to the commenter's concerns about changes in the climate and the rate of infiltration, the amount of water moving through the mountain is one of the key parameters in the projection of contaminant movement. As described in Section 5.2.4.1 of the EIS, modeling the performance of the repository included a range of water fluxes corresponding to variations in rainfall over thousands to hundreds of thousands of years due to climate changes. Moreover, it was assumed that the current climate is the driest it will ever be at Yucca Mountain.

With respect to surface water, Section 4.1.3 of the EIS addresses potential impacts during the construction, operation and monitoring, and closure phases of the proposed repository. Sections 6.3.2 and 6.3.3 address potential impacts of transporting spent nuclear fuel and high-level radioactive waste on branch rail lines and heavy-haul truck routes in Nevada, respectively. These sections discuss potential impacts to both surface water and groundwater along the routes DOE evaluated. In all cases, DOE believes that there would be very little potential for release of radioactive constituents. Sections 4.1.8 and 6.2.4 address potential impacts at the repository and from transportation activities, respectively, from accidents. Such impacts would be in the form of exposures to people, which DOE believes would be the primary concern before the completion of response and cleanup actions. Consistent with this position, DOE assumed that transportation accidents would occur in an urban area where impacts would be greatest. It did not evaluate specific impacts to Death Valley National Park, Ash Meadows National Wildlife Refuge, Wilderness Areas, or the Amargosa River as a result of accidents. None of the transportation routes would go through the Death Valley National Park.

Addressing the commenter's concerns about radioactive leaks from the repository affecting surface-water springs, the assessment of long-term repository performance described in Chapter 5 does not address such a scenario primarily because there are no springs along the groundwater flow path between Yucca Mountain and Alkali Flat, which is the area farthest from the repository for which DOE estimated impacts. In addition, the use of spring water would not represent a higher risk to water users than that assumed for the groundwater exposure scenario examined by DOE. That scenario includes residents using and consuming groundwater and consuming crops and livestock watered with groundwater. Finally, springs in Death Valley that may discharge some water from the Yucca Mountain area are farther from the repository than Alkali Flat. As a consequence, potential contaminant levels and exposure impacts in Death Valley would be lower than those estimated at Alkali Flat (modeling shows that doses resulting from contaminant releases would be within the regulatory limits established by EPA in 40 CFR Part 197).

7.5.3.2 (9398)
Comment - EIS001653 / 0038
Groundwater section [Section 3.1.4.2]-There appears to be no discussion of baseline conditions associated with underground weapons testing program. This needs to be included in the DEIS. The DEIS does not account for all sources of chemically toxic constituents in groundwater, including documented background conditions (e.g. barium, manganese), and contributions from the Nevada Test Site.

Response
The last paragraph of Section 3.1.4.2.2 of the EIS describes the relationship between activities on the Nevada Test Site and groundwater conditions at Yucca Mountain. As indicated, there are no impacts to groundwater at Yucca Mountain from activities on the Test Site. In addition, Section 8.3.2.1 discusses the cumulative impacts of underground weapons testing at the Nevada Test Site. Section 8.3.2.1.1, which cites DOE (DIRS 101811-1996), addresses the transport of contaminants in groundwater and DOE (DIRS 101811-1996) contains a detailed discussion of underground weapons testing.

Regarding the assertion that the EIS does not account for all sources of chemically toxic constituents in groundwater, including background conditions, Sections 3.1.4.2.1 and 3.1.4.2.2 of the EIS discuss existing groundwater quality on a regional scale and at Yucca Mountain, respectively. Section I.6 addresses the potential for the repository to add toxic materials to the groundwater. As described in that section, DOE did a screening analysis to focus on realistic human health hazards from waterborne toxic chemicals. The repository would contain many materials that could result in impacts to human health. However, most of those materials would not be present in large enough quantities or would not dissolve readily enough in water to pose a risk. To evaluate the potential risk posed by these materials, an analysis could rigorously evaluate every material (at great cost), or could apply a screening analysis to identify materials with too little inventory or too little solubility to be of concern. The screening analysis that DOE applied was a simplified scoping calculation, which resulted in a short list of materials that merited further consideration. It treated preliminary concentrations predicted under the simplified assumptions as conservative estimates used only to determine if DOE should rigorously model the material again using the performance assessment model. For materials that the screening analysis indicated must receive further evaluation, DOE computed more realistic concentrations and impacts with the performance assessment model, as reported in Sections I.5 and I.6.

7.5.3.2 (9715)
Comment - EIS002151 / 0005
Scientific evidence confirms what the Shoshone Nation have taught all along, Yucca Mountain is moving. It's extremely unstable with thirty-three fault lines, a nearby active volcano, geothermal activity and fissures throughout the mountain. I've heard from scientists and watched the water from the rain go right through the mountain and this water will definitely reach where the nuclear waste is stored, and that's something that those openings at the

downpours can travel through, it shows how unstable that mountain is. It's not a safe place for nuclear waste. It's not a sane place for nuclear waste. It's a political place for nuclear waste.

Response
DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, which considered faults, earthquakes, volcanism, and fast-flow movement of water through the mountain, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

In 1987, Congress selected Yucca Mountain as a proposed location for a monitored geologic repository, and directed DOE to determine whether the site is suitable (Nuclear Waste Policy Amendments Act of 1987). Some of the reasons that Congress selected Yucca Mountain for study included a deep water table; favorable geology; a desert environment; and the fact that the Nevada Test Site was already a controlled area. Another reason for the decision to study only one site was the rising costs of the overall program. Congress recognized that costs could be reduced by selecting and studying the best site, rather than studying several sites simultaneously.

The Secretary of Energy will consider the results of site characterization, the Final EIS, and other project documents in determining whether to recommend to the President that Yucca Mountain be developed as a repository.

7.5.3.2 (9787)
Comment - EIS001888 / 0373
[Clark County summary of a comment it received from a member of the public.]

One commenter asked if the EIS will discuss monitoring of potential subsidence at the surface caused by underground excavations, and if numerical modeling of underground stresses will be conducted.

Response
DOE agrees that the potential effects of in-place stresses and of mining the underground waste emplacement openings are important aspects of the repository program. The design of the proposed repository requires knowledge of the magnitude, direction, and variability of preconstruction in-place stress. DOE needs this information to analyze and design stable underground openings and to predict short- and long-term rock-mass deformation. DOE has been modeling in-place stress and the potential effects of thermal loading on the waste isolation properties of Yucca Mountain since the early 1980s (DIRS 101314-DOE 1986). At that time, data indicated that the repository host rock "can accommodate expected mechanical and thermal stresses after closure" (DIRS 101314-DOE 1986). Analyses also indicated that the heat load "can be adjusted to account for unforeseen problems."

The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) cites reports that contain the results of in-place stress tests at and near Yucca Mountain. That document also summarizes estimated in-place stress at the repository level and the results of more recent testing in the Drift Scale Test block. Section 11 of the Site Description describes the integrated system response to the heat generated by emplaced waste. That section considers the part of the natural system, the near-field environment zone, that thermal effects would permanently alter. Although the far-field environment could have slightly elevated temperatures, it would remain essentially unaltered (DIRS 151945-CRWMS M&O 2000).

DOE would continue to monitor and analyze rock-mass response and deformation around the emplacement drifts as part of the performance confirmation program. Specifically, instrumentation at the surface over the repository would monitor uplift caused by thermal loading (DIRS 150657-CRWMS M&O 2000). Because the stresses at Yucca Mountain are so low, DOE would measure deformation around the emplacement drifts using stress-change gauges (DIRS 150657-CRWMS M&O 2000).

7.5.3.2 (9791)
Comment - EIS001888 / 0376
[Clark County summary of comments it has received from the public.]

Three commenters stated that the subsurface rock at Yucca Mountain is rotten (crumbles easily during tunneling), or has been fractured from underground testing of nuclear weapons, and that radioactive releases into this rock must to be evaluated.

Response
Although the rock at Yucca Mountain is fractured, experience gained during the excavation of the Exploratory Studies Facility indicates that tunnel openings remain relatively stable. DOE used extra support at several locations in the Exploratory Studies Facility (particularly along portions of the north and south ramps), but found no zones of crumbly rock in the 8-kilometer-long (5-mile-long) tunnel.

Rock fractures at the Yucca Mountain site are primarily natural features created by cooling of volcanic ash-flow deposits, crustal stresses in the Earth's crust, and near-surface stress release caused by erosion. DOE also noted that drilling induced some fracturing of the rock during rock-core recovery and logging. Rubble zones in several boreholes might be due to closely spaced fractures in the relatively brittle welded tuffs. Sections 4.6.6 and 4.7.3 of the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) discuss fractures in greater detail.

There is no evidence that past underground detonations of nuclear weapons on the Nevada Test Site have fractured the rock at Yucca Mountain or that radioactive releases from weapons testing have migrated outside the Nevada Test Site.

7.5.3.2 (9796)
Comment - EIS001888 / 0381
[Clark County summary of comments it has received from the public.]

Commenters requested that the EIS evaluate the impacts from reasonable changes in the level, and the potential for elevated temperatures, of the water table at Yucca Mountain. To support this issue, commenters cited the presence of "calcite opal mineral formations" along fractures as evidence of upwelling hot water, which could leach radionuclides into the environment, flash to corrosive steam in an already hot repository, and increase the risks of criticality. Another commenter noted the groundwater temperature of the Amargosa River as evidence of high temperature groundwater.

Response
Based on the results of analyses reported in Section 3.1.4.2.2 of the EIS, DOE does not believe that the waste emplacement drifts would be inundated by a credible rise of the water table. However, this section discusses evidence that the elevation of the water table at Yucca Mountain has fluctuated over time. The fluctuations have been due largely to changes in the climate. DOE examined the cumulative effects from a wetter climate, earthquakes, and a volcanic eruption on the elevation of the water table. Based on the evidence, no reasonable combination of these conditions could raise the elevation of the water table sufficiently to inundate the emplacement drifts at Yucca Mountain.

Section 3.1.4.2.2 of the EIS discusses several opposing views on fluctuations in the elevation of the water table at Yucca Mountain. Some investigators believe that the water table has risen in the past to elevations higher than the waste emplacement horizon. DOE does not concur with these views, nor did an expert panel that the National Academy of Sciences convened specifically to examine this issue (as described in Section 3.1.4.2.2). DOE believes that the geologic evidence strongly indicates that over the past several million years, water levels at Yucca Mountain have not been more than about 120 meters (390 feet) higher than the present level. Although DOE disagrees with the central conclusions in this report (DIRS 104875-Dublyansky 1998), it continues to support research in this area and other aspects of geology and hydrology that enhances the understanding of the site. DOE considers this additional research on fluid inclusions to be supplemental confirmatory research.

The temperature of groundwater generally varies with depth; deeper groundwater is usually warmer than shallow groundwater throughout the world. The temperature of the Amargosa River in the few areas where groundwater discharges to the surface does not indicate a deep subsurface source of geothermal energy or magma, but rather reflects the ambient temperature of the groundwater.

7.5.3.2 (9882)
Comment - EIS001888 / 0428
[Clark County summary of comments it has received from the public.]

Commenters requested that the EIS describe the seismic design and its basis, including deterministic evaluation of maximum credible seismic events based on ground motion, as well as resulting secondary effects such as transient or long-term changes to the water table.

Response
DOE is designing the surface and underground facilities at Yucca Mountain to withstand ground motion from earthquakes that were identified in the seismic hazard analysis. The analysis determined that for the 10,000-year earthquake, facilities would be designed to withstand ground motions from a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain and a magnitude 7.5 or greater earthquake in Death Valley 50 kilometers (31 miles) away. DOE regards this annual frequency to be appropriate and conservative because it reflects the annual probabilities of ground motions for nuclear powerplants in the western United States, and the surface facilities at Yucca Mountain pose less risk compared to nuclear powerplants.

Table 4-36 of the EIS describes earthquake accident scenarios with a recurrence frequency of once in 50,000 years. This is roughly equivalent to a magnitude 7 earthquake occurring within 5 kilometers (3 miles) of Yucca Mountain with a mean peak ground acceleration of approximately 1.1g at the repository level (not the surface). DOE considers these to be very conservative calculations that indicate the maximum impact of such an event.

The waste emplacement areas would be away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide releases. Additional fault displacements from post-emplacement seismic activity would probably be along existing faults. DOE developed its hydrologic models of Yucca Mountain on a fault-fracture dominant flow system. The generation of new faults and associated earthquakes would have minor or no effects on fault and fracture pathways, and therefore would be unlikely to alter repository performance. Modeling of the long-term performance of the repository shows that the combination of natural and engineered barriers at Yucca Mountain would keep doses resulting from any contaminant releases well below the regulatory limits established by 40 CFR Part 197.

DOE has maintained a network of boreholes to monitor water levels at and near Yucca Mountain over the past two decades. Measurements of water-level elevations under normal conditions show only minor annual changes (a few tenths of a meter) due to seasonal variations in precipitation. Several boreholes record water levels continuously or for short intervals (several times an hour). These boreholes have recorded the response of the water table to both local earthquakes (including the magnitude-5.6 Little Skull Mountain earthquake in 1992) and regional earthquakes (some as large as magnitude 7.3, such as the Landers, California, earthquake, on June 28, 1992). In general, departures from long-term average water-table elevations are minor, usually limited to a few centimeters to about 1 meter. These changes are generally short-lived, with most monitored boreholes showing a return to pre-earthquake water levels within a few hours to a few days. In no instance has the network recorded any large permanent departures from pre-earthquake water levels.

7.5.3.2 (10082)
Comment - EIS001465 / 0008
When they got down in Yucca Mountain, my friend saw that there was water dripping from cracks in the ceiling and that there were puddles of water on the ground. And the Department of Energy tells us that Yucca Mountain is completely dry, that there’s no water that moves through it, and yet they found contamination from above ground testing 500 feet below the surface of Yucca Mountain. How does this contamination get there from above ground testing if it’s not carried there by the water? The Department of Energy is lying to us.

Response
Without knowing where in the exploratory studies facility the water was observed, DOE cannot respond with precision. However, water is used to wash the tunnel walls before sampling and testing, and for dust control. The

water observed may have been from such activities. It seems more likely, however, that the dripping water was in Alcove 5 where the Drift Scale Heater Test is being conducted. One of the main objectives of the heater test is to monitor the response of the repository host rock to heat from simulated waste packages. An important and expected result of the heater test is that water in the pores of the rock is converted to water vapor. The water vapor then migrates through connected fractures in the rock until it finds an outlet in more remote, cooler portions of the rock mass. Encountering cooler rock causes the water vapor to condense into water. In the vicinity of the heater test, the most accessible location in which this recondensed water can accumulate is the air-conditioned visitors' gallery adjacent to the heater drift. Any water observed dripping into the visitors' gallery does not originate from percolating surface infiltration; it is entirely the result of this anticipated response of the rock pore water to the imposed heat load.

Regarding the infiltration of surface water to the depth of the waste emplacement area, DOE specifically acknowledges in Section 3.1.4.2.2 that post-1952 infiltration of surface water has reached the waste emplacement area. The Department believes that such rapid movement of water occurs along faults and fracture zones. This phenomenon has been factored into modeling of fluid flow in the unsaturated zone and total system performance analysis.

7.5.3.2 (10083)
Comment - EIS001465 / 0009
One of my friends reached out and touched the wall of Yucca Mountain, the tunnel, and with his hand he took off a big chunk of rock and crumbled it. That's not a solid rock. That's like sandstone or something. There's no way that Yucca Mountain can contain the nuclear waste [that] is going to be contained for a lot more than 10,000 years, and under this process DOE is only looking at 10,000 years.

Response
The Exploratory Studies Facility at Yucca Mountain extends from the surface to the waste-emplacement area. The rock between the surface and the waste-emplacement area consists of layers of welded and nonwelded tuff. Without knowing the particular rock layer or depth at which the rock from the wall was handled, it is difficult to specifically address this comment. However, the rock layers above the waste-emplacement area could be considerably different. Moreover, a rock's resistance to crumbling might indicate little about its ability to isolate waste. For example, the salt in which the Waste Isolation Pilot Plant in New Mexico was constructed can be crumbled by hand, but the formation has been stable for an exceptionally long period of time. DOE has studied the physical characteristics of many rock samples at Yucca Mountain, as well as how the entire mountain responds to large-scale processes and events, including precipitation and infiltration, erosion, earthquakes, and heat build-up.
Chapter 5 of the EIS describes impacts to human health from radioactive and nonradioactive materials released to the environment during the first 10,000 years after closure. This chapter also describes the peak radiation dose during the first 1 million years after closure.

7.5.3.2 (10123)
Comment - EIS002076 / 0001
I believe the draft EIS does not sufficiently address the geology and water issues. Therefore, my concerns are the stability of the geological structure of Yucca Mountain and the potential contamination of ground water by any type of contamination, including and especially nuclear waste. In the event of a major earthquake and possible damage to and leakage of waste, which could contaminate the underground water, is my greatest concern. Contamination of underground water which eventually through underground rivers, streams, or connecting aquifers could end up in the Colorado River, thus contaminating the waters of Havasu Lake and reservations.

Response
DOE has conducted an extensive site characterization program to evaluate the proposed repository at Yucca Mountain. Yucca Mountain is in the Death Valley regional groundwater flow system. This basin is a closed hydrologic basin, which means its surface water and groundwater can leave only by evaporation from the soil and transpiration from plants. This area is characterized by a very dry climate, limited surface water, and very deep aquifers. The regional slope of the water table (potentiometric surface) indicates that the groundwater from beneath Yucca Mountain flows southward toward Amargosa Valley. The central Death Valley subregion is comprised of three groundwater basins that are divided into smaller sections.

Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin. In this basin, only a small potion of total basin recharge actually infiltrates through Yucca Mountain. The small fraction of water that does infiltrate through Yucca Mountain eventually recharges the groundwater, then flows towards Fortymile Wash and merges with the rest of the groundwater in the Fortymile Canyon section of the groundwater basin. Flow then continues south toward Amargosa Valley and mixes into the very large groundwater reservoir in the Amargosa River section, as shown in Figure 3-15 of the EIS. The natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, 60 kilometers (37 miles) away. None of the groundwater in the Death Valley regional groundwater flow system enters the Colorado River or Lake Havasu.

Extensive studies conducted at Yucca Mountain show evidence of low infiltration and percolation rates, long groundwater residence times, and a repository horizon that has been hydrologically stable for long periods. The proposed waste-emplacement areas would be in areas away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release. Additional fault movements and associated seismic activity would probably be along existing fault planes.

Hydrology models, derived from studies conducted at Yucca Mountain, are based on a fault-fracture dominant flow system. The addition of a few new faults by earthquakes would have negligible effects on the current fault- and fracture-flow pathways, and would not be likely to alter the long-term performance of the repository. DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 for more information).

7.5.3.2 (10264)
Comment - EIS002204 / 0001
Just a few years ago at Yucca Mountain itself, they found contaminated tritium from above-ground testing 500 feet below the surface of Yucca Mountain.

This contaminated tritium was from the nuclear explosions that would explode into the air, the contamination would come down, fall on the surface and then with the rain water that was falling on the mountain would be carried 500 feet below the surface of the ground. The water is moving through Yucca Mountain. Friends of mine went out to Yucca Mountain just a couple weeks ago, about a month ago, actually, and took a tour of the Yucca Mountain, and where the gentleman was talking about where they're heating up the rocks, there is water pouring out of those rocks.

There are puddles of water on the floor, condensation all over the tunnel, and the people at Yucca Mountain were trying to shield it, trying to put up these aluminum shields to hide that water so that it would go around these shields and underneath the walkway so that the people walking through there couldn't see the water.

Response
One of the main objectives of the heater test is to monitor the response of the host rock at Yucca Mountain to the effects of heat imposed on the rock from simulated waste packages. An important and expected result of the imposed heat is to cause the water in the pores of the rock to be converted into water vapor. The mobilized water vapor then migrates through the connected portion of the rock fracture network until it finds an outlet in more remote, cooler portions of the rock mass. Encountering cooler rock causes the water vapor to recondense into liquid. In the area of the heater test, the most accessible location for this recondensed water to accumulate is the air-conditioned visitors gallery adjacent to the heater drift. Water seen dripping into the visitors gallery originates from this process.

The purpose of the aluminum shielding is not to hide the water that becomes mobilized. The aluminum shielding, along with insulation behind the shielding, creates an acceptably cool environment that allows visitors and scientists alike, to be in the immediate vicinity of the heater test.

As part of its site characterization activities, DOE has conducted a variety of investigations into the nature of water falling as precipitation on Yucca Mountain and passing through the unsaturated zone to the groundwater beneath.

One such study has been to quantify the concentrations of certain radioisotopes in the Exploratory Studies Facility. Isotopes, such as chlorine-36 and tritium, which occur naturally and as a byproduct of atmospheric nuclear weapons testing, serve as indicators of the rate of flow through the unsaturated zone (see Section 3.1.4.2.2 of the EIS for details).

Results from preliminary studies have identified these isotopes in concentrations that tend to suggest that there are connected pathways through which surface precipitation has percolated to the repository horizon within the last 50 years. However, these isotopes have been found at locations that are almost exclusively associated with known, through-going faults and well-developed fracture systems close to the faults at the proposed repository horizon.

To ensure the correct interpretation of this chemical signal, DOE instituted additional studies to determine if independent laboratories and related isotopic studies can corroborate the detection of elevated concentrations of these radioisotopes. Results of the validation studies to this point have not allowed firm conclusions and, thus, the evaluations continue.

DOE believes that these findings do not indicate that the Yucca Mountain site should be declared unsuitable for development as a repository. Most of the water that infiltrates Yucca Mountain moves slowly through the matrix and fracture network of the rock, and isotopic data from water extracted from the rock matrix indicates that residence times might be as long as 10,000 years. Furthermore, after excavating more than 11 kilometers (8.4 miles) of tunnels at Yucca Mountain, DOE determined that only one fracture was moist (there was no active flow of water). This observation has been confirmed in test alcoves that are not subject to the effects of drying from active ventilation.

Nevertheless, the total system performance assessment incorporates the more conservative water movement data as well as information from other water infiltration and associated hydrogeological studies. As a result of this evaluation, DOE would not expect the repository (combination of natural and engineered barriers) to exceed the prescribed radiation exposure limits during the first 10,000 years after closure.

7.5.3.2 (10349)
Comment - EIS002176 / 0002
We believe that the DEIS for Yucca Mountain is unacceptable for a number of reasons. Saturation of the Yucca Mountain repository is possible given numerous scientific findings including the detection of atmospheric bomb testing nuclides at repository depths and the inconsistent groundwater levels near the site. The DEIS must be rewritten to include the environmental impact of groundwater infiltration and saturation.

Response
DOE agrees that evidence of "nuclear-age" water reaching the depth of the proposed repository has shown that water at the surface moves through rock fractures and faults at Yucca Mountain and is a component of the long-term performance of the Yucca Mountain site. While evidence of such water is an indication of the rate at which water can percolate through the unsaturated zone, it is not evidence of saturation. DOE believes there is no evidence that groundwater beneath Yucca Mountain would ever rise as high as the level of the proposed repository. Section 3.1.4.2.2 of the EIS discusses geologic evidence at the site indicates that during wetter geologic times, groundwater was as much as 120 meters (394 feet) higher than it is today. Nevertheless, this would still be below the level of the proposed repository. Section 3.1.4.2.2 also recognizes that there are opposing views concerning the past elevation of the water table beneath Yucca Mountain. The text summarizes these opposing views and the reasons why DOE does not concur with them.

It is unclear what this comment means by "inconsistent groundwater levels near the site." Section 3.1.4.2.2 of the EIS describes groundwater levels at Yucca Mountain, which have been very stable since site characterization studies began in the early 1980s. If the comment is referring to the large hydraulic gradient north of the site, this feature is described in Section 3.1.4.2.2. An expert panel convened by DOE addressed this issue and narrowed the theories of its origin to two credible scenarios. Under one scenario, the gradient is the result of flow through the upper volcanic confining unit where water moves very slowly. Under the other scenario, the gradient is actually a perched or semiperched water body above the water table where flow is essentially vertical. Under this second scenario, the elevation and location of the perched water could change quickly if it drained downward into the lower volcanic aquifer. The consensus of the panel favored the perched water theory. However, the experts were in agreement that the issue was only of technical curiosity because there is no evidence to suggest that this large hydraulic gradient would affect the performance of the repository.

7.5.3.2 (10464)
Comment - EIS002221 / 0002
The other thing I say is I demand they stop this Yucca Mountain Project because the water has been denied to the project.

The environmental assessment says nothing about, you know, what kind of impact having all these trucks and all this water being trucked in, and without the water, the project is a dead duck, and, you know, if it looks like a duck and walks like a duck, figure it out.

Response
On February 22, 2000, the Nevada State Engineer denied DOE's water-appropriation request for 430 acre-feet of water per year for repository construction and operation. DOE filed suits on March 2, 2000, in U.S. District Court for the District of Nevada, and on March 3, 2000, in Nevada's Fifth Judicial District Court, for injunctive relief to overturn this ruling (Nevada State Engineer's Ruling #4848). The State Engineer based his denial on a finding that the requested use threatened to prove detrimental to the public interest.

On September 21, 2000, the U.S. District Court granted the State's motions to dismiss the DOE lawsuit. DOE appealed this ruling on November 16, 2000. On October 15, 2001, the Ninth U.S. Circuit Court of Appeals ordered a Federal judge to hear the DOE's suit. The case is pending.

DOE has not developed any other plans to acquire water for construction and operation of the proposed repository. Depending on the final ruling of the State court, the Department might consider other options to carry out its responsibilities under the NWPA.

7.5.3.2 (10595)
Comment - EIS002147 / 0003
But I do know the water's a thousand foot down. We have radioactive devices right over there at the test site saying they're cooking, will cook for who knows how many thousands of years. They are in the water table. What's going to be stored in Yucca Mountain is not a problem with the water table. Nothing like what's already out there.

Response
Chapter 8 of the EIS evaluates impacts from other Federal, non-Federal, and private actions that could be cumulative with those from the proposed repository. Section 8.3.2.1 addresses the impacts from activities at the Nevada Test Site, including the magnitude of contaminants from past weapons testing that could migrate through the same locations, or pathways, as those evaluated for the long-term performance of the repository.

7.5.3.2 (10711)
Comment - EIS000088 / 0004
We all know in this valley here the water moves. It's not like what the DOE geologists are telling us, it only moves an inch a year.

If it moves more than that. When this earth of ours rotates, what does it do to that water inside of it just like in the jug? That's what it does. It keeps on moving and on moving.

It's got so much radiation in our water throughout the world today, there's no safe water anymore left.

Response
Studies at Yucca Mountain suggest that contaminants in groundwater would travel from the repository to the accessible environment 20 kilometers (12 miles) away in many thousands to tens of thousands of years. It would take even longer for this groundwater to reach natural discharge areas at Franklin Lake Playa more than 60 kilometers (37 miles) south of the repository.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

7.5.3.2 (10756)
Comment - EIS001886 / 0009
Draft EIS does not analyze the potential impact of inundation of the repository zone by upwelling water.

Draft EIS acknowledges that inundation of the repository zone by upwelling water, if happens, would have great impact on the long-term repository performance.[1] The possibility of such inundations was suggested by a number of scientists (Szymanski, 1989; Hill et al., 1995). Draft EIS explicitly states, however, that "DOE does not agree with the inundation scenario" (p. 5-15). This dismissal heavily rests on the findings of the 1992 NAS/NRC panel (National Research Council, 1992). The latter document is outdated, because much new data have became available since 1992. Below we summarize some of this evidence.

Fluid inclusion evidence

By rejecting "inundation scenario", DOE rejects new scientific information indicating the presence of waters with elevated temperature in what is now Yucca Mountain unsaturated zone in the past, obtained by studies of fluid inclusion in secondary minerals.[2] "Justification" of this rejection is given on pp. 3-49 - 3-50 of the Draft EIS as follows: "DOE, given the opportunity to review a preliminary version of the report, arranged for review by a group of independent experts, including U.S. Geological Survey personnel and a university expert. This review group did not concur with the conclusion in the report by Dublyansky (1998 all)..."

The quotation above reflects lack of objectivity in the DOE's handling of the controversy. First, experts who conducted the review for the DOE may hardly be called "independent," since all these scientists were promoting the "non-inundation" scenario for years.[3] Second, it is unfair and misleading not to mention written opinions of three truly independent experts from the Europe (selected for their outstanding scientific expertise in fluid inclusions and non-involvement in the Yucca Mountain studies),[4] attached to the report. All three reviewers concurred in the opinion that the fluid inclusion work is of high quality, and interpretations are reasonable.

Further, the U.S. NWTRB has agreed with the "thermal water" interpretation of the fluid inclusion data.[5]

Finally, a DOE-sponsored verification fluid inclusion research project presently underway at University of Nevada at Las Vegas, UNLV, has already (as of July, 1999) confirmed the presence of the two-phase fluid inclusions, yielding elevated homogenization temperatures in secondary calcite and quartz from ESF.

Other evidence

Besides fluid inclusions, the presence of hot waters in what is now unsaturated zone at Yucca Mountain is suggested by a host of other methods.

a). The USGS geologists inferred elevated, up to 120ºC, temperatures for paragenetically early secondary silica from ESF on the basis of stable isotopic studies.[6]

b). Based on yet another method, structural studies of calcite, Mary Beth Gray with co-authors (contractors to NRC) concluded that calcite in fault rock in the ESF were formed at elevated temperatures (probably, 150-200ºC), and there have been more than one event of calcite deposition (Gray et al. 1998).

c). Terry Else with co-authors (1999) have found viable moderately thermophilic calcite-depositing bacteria (temperatures of habitat 40-60ºC) in calcite sample that yielded homogenization temperatures of 35-50ºC; adjacent bedrock tuffs did not contain such bacteria.

d). Preliminary data on stable isotopic gradients in surficial calcite at Yucca Mountain suggest the progressive evaporation, CO_2 degassing and perhaps cooling -- features consistent with travertine origin and inconsistent with pedogenic origin of these deposits (Dublyansky and Szymanski 1996; Dublyansky et al. 1998). Prof. John Valley, who evaluated this work for the U.S. NWTRB [Nuclear Waste Technical Review Board], concurred with this interpretation (with one reservation that the presence of these trends needs to be verified).[7]

Hydrothermal activity at Yucca Mountain -- Summary

The status of the issue was best summarized by former consultant to U.S. NWTRB, Prof. Robert Bodnar, at the 1999 Spring Meeting of the American Geological Society in Boston, Massachusetts: "Those scientists who have examined the recent data are in general agreement that waters of unknown but, presumably, deep origin have entered the repository horizon at some time during the geologic past.... The problem as it relates to the suitability of Yucca Mountain as a nuclear waste repository concerns the timing of fluid infiltration." (Bodnar 1999).

Elevated temperatures of secondary minerals deposition imply inundation of the Yucca Mountain unsaturated zone by upwelling water, provided two alternative sources of heat -- residual heat of cooling bedrock tuffs and conductive heat transfer from deep-seated magmatic bodies -- are ruled out. In the case of Yucca Mountain this requirement is met. Different researchers at different times have ruled out magmatic rocks as a potential source of hydrothermal activity at Yucca Mountain.[8] Isotopic dating by USGS researchers have shown that the oldest secondary minerals at Yucca Mountain were deposited 2 to 3 million years after the emplacement of the tuffs (Neymark et al. 1998; Whelan and Moscati, 1998), which means the latter have already cooled down.

Timing of hydrothermal inundation

Frequency of occurrence of the hydrothermal activity and, therefore, the probability of its occurrence in the future cannot presently be established with confidence due to lack of the data. The DOE-sponsored Project[9] which is presently underway at University of Nevada at Las Vegas, will, hopefully, substantially advance our knowledge on the timing of hydrothermal activity at Yucca Mountain.

Nevertheless, there is already enough evidence suggesting that thermal fluids were present in the repository zone, constantly or intermittently, during the extended time span of ~9-10 million years, with youngest occurrences being only few thousand years old. These young isotopic ages have been measured for calcite from the ESF by the USGS researchers (e.g., Paces et al. 1996).[10] Based on the preliminary data, the hydrothermal activity has probability of occurrence greater than the lower limit of 1×10^{-8} per year adopted by DOE as the level of concern (DOE 1998, p. 4-81).

Why it is important?

Water is the primary means by which radionuclides disposed of at Yucca Mountain could reach the accessible environment. The present repository concept critically relies upon the following factors: (a) small amounts of water (seepage in repository drifts) that may contact waste canisters; (b) small fraction of waste canisters that would contact with this water (because seepage is restricted to individual fractures); (c) high corrosion resistance of waste canisters in the predicted repository environment (moderate temperatures, oxidizing water, etc.); and (d) long pathway between the repository and accessible environment (including 175 to 365 m of the unsaturated zone beneath the drifts and about 20 km of saturated-zone flow to Amargosa Valley; with dispersal of radionuclides along the way).

However, if inundation scenario is considered, these factors are not the most important ones, for the following reasons:

Amount of water, contacting waste canisters. Instead of small amounts of seepage water contacting some waste canisters, all canisters will be completely submerged in water with composition totally different from today's meteoric water.

Corrosion resistance of waste canisters. Since the composition and the temperature of upwelling water will differ from meteoric water, the present assessment of waste package degradation rates cannot, therefore, be used for such dramatically different environment.[11] Preliminary data indicate that corrosion-resistant component of the base-case canister, alloy C-22, "...is susceptible to localized corrosion...when wet in a critical temperature range. If C-22 remains passive in this range, its anticipated life, prior to penetration, is thousands of years. If it is not passive, then its life, prior to penetration, is as little as a few tens of years" (Whipple et al., 1998).

Long radionuclide pathway. Long pathway of water, contaminated with radionuclides from repository zone through 175 to 365 m of the lower part of the unsaturated zone, and then through some 20 km of saturated zone to the extraction wells in Amargosa Valley, will be replaced by a 200 to 425 m-long "shortcut" right to the land surface, where these waters would discharge as springs.

"Hot repository" consequences. If inundation occurs during the period when the repository zone is still hot due to the radioactive decay (a period that may last several thousand years), the consequences may change dramatically. Much will depend on the temperature of rocks and waste canisters, with which water comes into contact. This temperature will depend on time elapsed since emplacement, as well as the chosen thermal load. A set of scenarios may be constructed for water invasion in the repository zone when: (1) the temperature is well above water boiling point; and (2) when it is below boiling, but still higher than the temperature of upwelling fluids. Vigorous boiling and steam venting may be envisaged for the first scenario and enhanced convection of water for the second. Both these scenarios envisage faster failure of the canisters, thereby enhancing the ability of radionuclides to migrate.

Summary on inundation scenario

We have demonstrated that:

a. There presently exists significant body of evidence, indicating that inundation of the repository zone by upwelling hot waters.

b. The ages of these events are presently not known with certainty; extensive preliminary data indicate, however, that they occurred intermittently between 9 million years and 8 thousand years ago.

c. Based on the present evidence, it is reasonable to conclude that the probability of occurrence of inundation is greater than the 1×10^{-8} per year DOE level of concern, which means that the hydrothermal hazard probabilistic analysis must be carried out.

d. Potential consequences of inundation of the repository filled with high-level nuclear waste may be disastrous for the environment and people.

e. Draft EIS does not consider the inundation scenario.

In our judgement, the failure to consider this important scenario makes the present Environmental Impact Statement completely inadequate and cannot be used for evaluating real environmental impact of the planed facility. "Inundation" issue must be explicitly resolved prior to any decision regarding the fate of the Yucca Mountain site.

[1]"There has been no analysis to determine the effect; however, if such an event occurred, the long term impacts would probably increase greatly." (p. 5-11) [5-15]

[2]Dublyansky and Reutsky 1995 and 1998; Dublyansky et al. 1996; Dublyansky 1998-a and -b.

[3]Authors of the review, arranged by DOE are: J.Whelan, J.Paces, B.Marshall, Z.Peterman, J.Stuckless, L.Neymark of USGS and E.Roedder of Harvard University.

[4]Independent experts who evaluated Dublyansky 1998 report are: Dr. Larryn Diamond, University of Leoben, Austria; Dr. Bruce Yardley, University of Leeds, UK; and Dr. Jean Dubessy, CNRS, France.

[5]"... fluid inclusions found in mineral deposits at Yucca Mountain do provide direct evidence of the past presence of fluids at elevated temperatures ... in the vicinity of the proposed repository" (letter of the Chairman of the U.S.

NWTRB Jared Cohon to Acting Director of the U.S. DOE Office of Civilian Radioactive Waste Management Lake Barrett; July 24, 1998, p. 2)

[6]"Delta-^{18}O values of the silica phases quartz, chalcedony, and opal indicate that some of the early massive-silica-stage phases must have formed from heated water..." Whelan et al. 1998, p.21.

[7]"These trends deserve close examination. If such trends are reproducible and are in fact different from local elevation effects, this would be strong evidence favoring progressive evaporation and COsubscript2 out-gassing (and perhaps cooling) as fluids move down slope." Letter from Prof. J.Valley to L.Reiter of NWTRB; Dec. 18, 1997. p.4.

[8]"Silicic volcanism located close enough to Yucca Mountain to have provided heat to the local hydrologic regime ended more than 11 Ma. Magma bodies below larger calderas (>10 km diameter) cool slowly and may be heat source for up to 2 Ma (Wohlentz and Heiken, 1992). Calculations based on theoretical cooling model (Smith and Shaw, 1978) indicate that magma chambers associated with calderas of the central zone of the Southwestern Nevada Volcanic field would have completely crystallized and cooled to ambient temperature several million years ago." Flynn et al., 1995, p. 27.

[9]The project term begun in April, 1999 and is scheduled to end by April, 2001.

[10]The authors interpret this calcite as being deposited from rain waters percolating downwards through interconnected fractures. Recent results of Dublyansky (1999) and UNLV Committee have shown that 40 to 70 % of calcite from the ESF (including calcite from some occurrences dated by USGS), as well as some quartz, contain two-phase fluid inclusions indicating elevated, up to 60-80ºC, depositional temperatures.

[11]"No rational materials selection can be made without knowledge of the characteristics of the waters in contact with the waste packages. These characteristics include: temperature, pH, Eh and ionic concentrations (Cl, SO_4, NO_3, CO_3, Fe_{all+++}, Ca, etc.)" Third Interim Report of the Peer Review Panel on the TSPA 1998.

Response

In addition to the findings of the 1992 report by the National Academy of Sciences (DIRS 105162-National Research Council 1992), DOE scientists have reviewed documents and data on groundwater inundation that have become available since 1992.

In January 1997, the Nuclear Waste Technical Review Board (NWTRB) received 11 reports from Jerry Szymanski with new information that the Academy had not considered, as well as three additional reports the Nevada Attorney General's Office. The NWTRB reviewed this new information, after which the it concluded: "The material reviewed by the Board does not make a credible case for the assertion that there has been ongoing, intermittent hydrothermal activity at Yucca Mountain or that large scale earthquake-induced changes in the water table are likely at Yucca Mountain. This material does not significantly affect the conclusions of the 1992 NAS report." DOE does not disagree that inundation of the proposed repository with hot water would be a condition adverse to performance, but based on the arguments and information presented in response to specific allegations, DOE scientists do not consider such an event a viable possibility.

With regard to fluid inclusions, the report by Dublyansky (DIRS 104875-1998) ignores all data that are contrary to the thesis of upwelling water. These data form a major part of the basis for rejecting the upwelling or inundation hypothesis. The opinions of three outside experts who were not familiar with all the data pertinent to Yucca Mountain should not be used to unequivocally support the conclusion of Dublyansky (DIRS 104875-1998). The fact that the fluid inclusion data may be of high quality and consistent with Dr. Dublyansky's conclusion does not prove that the conclusion is correct, because other, much different conclusions are also consistent with the fluid inclusion data. Furthermore, a large body of data exists that are in conflict with the inundation theory.

With regard to the NWTRB agreeing with the thermal-water interpretation of fluid-inclusion data, the Board noted that the timing of a thermal event is critical to evaluating the hypothesis of intermittent thermal activity. DOE agrees that there has been past thermal activity, but there is currently no evidence of such activity beyond the early stages of secondary mineral formation, in which case the heat source was probably the igneous activity that formed the southwest Nevada volcanic field. Furthermore, late calcite, as defined by textural, chemical and age determinations, spans at least the past 2 million years and contains no evidence of thermal activity.

With regard to hot water in what is now the unsaturated zone at Yucca Mountain, the early secondary silica referred to is older that 8 million years and is not of concern to the performance of a repository now or in the future.

With regard to the structural studies of calcite by Mary Beth Gray and others, the presence of elevated temperatures within a fault zone, if confirmed, does not seem surprising because frictional heating can be locally important. Furthermore, without a constraint of time, these deposits might have formed close to the time of volcanism when faulting was most active and igneous heat sources were available. The current thermal regime is similar to and perhaps part of the Eureka low, which is an adjoining area of anomalously low heat flow.

With regard to the study by Terry Else and others (1999), this reference was not provided and therefore could not be evaluated. However, as stated above, elevated temperatures do not demonstrate inundation, and the timing of the thermal pulse apparently is not constrained.

With regard to that part of the comment suggesting that travertine did not originate from a pedogenic source, the trend referred to was described by the NWTRB as one of the "Examples [that] include the very tenuous fits of lines to scattered small data sets showing presumed stable-isotope changes with depth and distance." The Board later concluded that "…because of the lack of any substantive evidence of ongoing hydrothermal activity, the Board views additional research on this subject (if not already carried out) as generally having a lower priority than more important issues in the evaluation of repository performance."

With regard to Bodnar (1999), DOE scientists who are familiar with the data do not agree with the assertion that the water is of "presumably, deep origin." Professor Bodnar's statement is printed in the supplement to *EOS, Transactions of the American Geophysical Union*, dated April 27, 1999. The same abstract notes "if the waters entered the horizon after the Timber Mountain Caldera event (10-13 MA), and if no heated waters have subsequently entered the site, then the fluids have little relationship to assessing the probability of future hot water at Yucca Mountain." DOE concurs that the early thermal activity described by Professor Bodnar is substantiated by available data.

With regard to the assertion that elevated temperatures of secondary mineral deposition implies inundation of the unsaturated zone by upwelling water, footnote 8, cited in the comment, says "cooled to ambient temperature several million years ago." The temperatures calculated from fluid inclusions are only slightly above ambient. Thus, secondary minerals could have formed anytime up to several million years ago and still have formed above the modern ambient temperature, which is in accord with DOE's position. Again, formation at elevated temperature does not require inundation as assumed here. A warm 2-phase environment (unsaturated zone) is in better accord with the observed assemblages of fluid inclusions that have highly variable liquid-vapor ratios than a saturated environment.

With regard to the frequency of occurrence of hydrothermal activity, DOE has developed a very large database on the ages and isotopic compositions of the secondary minerals and is confident that the current geochronologic effort will substantiate current results.

With regard to evidence suggesting that thermal fluids were present in the repository zone, constantly or intermittently, during the extended time span of about 9 million to 10 million years, secondary minerals have formed throughout the last 10 million years. However, no minerals have been found that formed in a saturated environment, and no minerals younger than a few million years have been found that formed at elevated temperatures. Furthermore, available data indicate deposition of secondary minerals during a long-term cooling period, rather than cycles of hydrothermal pulses.

7.5.3.2 (10899)

Comment - EIS000447 / 0007

The natural barriers of Yucca Mountain and its world class engineering will keep it away from the water. I've been there, and I've heard the comments on water. When they are talking about water, they are talking about a drip in dozens and dozens and dozens in hundreds and thousands of years. This is not a flow of water. This is moisture.

<u>Response</u>
DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

7.5.3.2 (11021)
<u>Comment</u> - EIS001896 / 0018
Section 4.1.3.3

There could be potential impacts on groundwater due to construction, operation, maintenance and closure of the Yucca Mountain facility.

<u>Response</u>
As described in Section 4.1.3.3 of the EIS, DOE expects that the impacts to groundwater during the construction, operation and monitoring, and closure of the repository would be minor. Groundwater pumping for use at the repository would decrease groundwater availability to some extent in downgradient areas. Section 4.1.3.3 points out, however, that the quantity of groundwater that would be needed for the repository would be small compared to the quantities currently being withdrawn in downgradient areas. Therefore, the Proposed Action would have very little effect on the availability of groundwater in these downgradient areas.

7.5.3.2 (11028)
<u>Comment</u> - EIS000475 / 0003
According to DOE, scientific determination of the rate at which water seeps into the Yucca Mountain repository is crucial to the facility's projected ability to meet performance objectives, i.e., containment of the HLRW. Rate of water seepage, according to DOE, directly impacts the period of time waste packages/containers will prevent release of radioactive materials into groundwater as well as the manner radioactive materials will eventually reach the groundwater table beneath the site. Heat generated by the waste within the repository likewise will affect the movement of water through the facility and the durability of the waste containers. Yet, DOE has shown considerable reluctance to scientifically investigate these areas. According to U.S. Geological Survey scientists, the large drop in the elevation of the water table (discovered in 1981) at the northern end of Yucca Mountain is the most striking hydrologic feature in the area and U.S.G.S. lacks data to explain its cause. Yet, no new boreholes and limited testing of groundwater to collect scientific data necessary to explain the hydrology of Yucca Mountain was done by U.S.G.S. for DOE from 1987-1997. In the alternative, DOE observed test pumping in an existing well indicated the drop in the water table at the northern end of Yucca Mountain has no effect on the flow of groundwater in the aquifer underneath the HLRW repository. It sounds like science, however, DOE has failed to investigate/collect data to determine the validity of the agency's preliminary observations concerning the hydrology of the site which is supposedly designed to secure HLRW for 10,000 years! Ref.: NUCLEAR WASTE, IMPEDIMENTS TO COMPLETING THE YUCCA MOUNTAIN REPOSITORY PROJECT, GAO/RCED-97-30, January 1997.

<u>Response</u>
DOE has used many methods to assess percolation or seepage rates in the unsaturated zone at Yucca Mountain and has collected more information on this topic than the EIS can present. The *Yucca Mountain Site Description* summarizes the methods DOE has used to characterize percolation, including generating estimates of percolation flux using borehole temperature and heat-flow data, chloride mass-balance methods, effective hydraulic conductivity or potential gradient methods, calcite accumulation rates, and perched-water volumes and residence times (DIRS 151945-CRWMS M&O 2000). In addition, the Site Description devotes a section to the studies and modeling to characterize how the natural system would respond to the thermal loading associated with the placement of radioactive waste, including thermohydrologic behavior, geomechanics, and geochemistry, as well as the results of thermal field testing in the Exploratory Studies Facility and how results of those studies compare to model predictions (DIRS 151945-CRWMS M&O 2000).

Section 3.1.4.2.2 of the EIS discusses the large hydraulic gradient. An expert elicitation panel addressed this issue and narrowed the theories of its cause to two credible scenarios: (1) flow through the upper volcanic confining unit where water movement is very slow or (2) measuring the surface of a perched or semiperched water system above the water table, where flow is essentially vertical. Under the second scenario, the water level could change quickly by depth and location as water was lost to downward seepage to the lower volcanic aquifer, and would be difficult to interpret. The panel favored the perched water theory. However, the experts agreed that the issue was only one of technical credibility. As stated in the DOE response to the General Accounting Office report referenced in the comment, "there is no evidence that the large hydrologic gradient will impact waste isolation." Further, the probability of a large transient change in the configuration of the large gradient is extremely low, and the long-term transient readjustment of gradients was of very low probability (DIRS 100116-CRWMS M&O 1996). The Site Description discusses the investigations of the large hydraulic gradient (DIRS 151945-CRWMS M&O 2000).

DOE has conducted an extensive site characterization program to evaluate the proposed repository site at Yucca Mountain. Through this program DOE has gained valuable knowledge of the flow system in the saturated and unsaturated zones. DOE recognizes that additional data would further define and reduce uncertainty about the long-term performance of the repository. The evaluation of the repository's long-term performance (summarized in Chapter 5 of the EIS) made conservative assumptions where necessary, realizing that information gained from ongoing studies could eventually support less conservative assumptions and estimates of impact. Section 5.2.4 discusses this philosophy for dealing with the uncertainties associated with evaluating the long-term performance of the repository.

7.5.3.2 (11088)
Comment - EIS002273 / 0003
Now, Yucca Mountain is a live mountain. The people that roam that part of the country drink from that mountain. The snake moves -- it's got a movement to it. It's going to get worser and worser. I know I have been told by my people long ago, when you are thirsty going through that part of the country, you could suck water from it.

And today the Nuclear Energy Department should realize there is water coming in. They don't know where it is coming from. But they are saying the rain is the reason why it's going through the mountain site, but it's not. It's a snake that lays there, carries water for the people. But it's hard for you people to understand.

Response
DOE is required to describe the affected environment and potential impacts from the Proposed Action in widely acceptable scientific terms and parameters. This comment nevertheless presents an apt analogy with respect to groundwater. The scientific facts recognize that water moves through the ground beneath Yucca Mountain, that its movements are complex and accompanied by many uncertainties, and that it makes itself available in this arid environment at springs and at shallow depths to those who understand its movements. Without considering the religious connotations of the comment, it is not difficult to associate these attributes of movement, complexity, and benevolence with a living thing. It is impressive that people, without benefit of data from subsurface exploration, would have historically linked these types of attributes to something they could not see.

Based on years of gathering data, DOE believes that the source of water moving through the unsaturated zone at Yucca Mountain is precipitation falling in the immediate area. The data in Section 3.1.4 of the EIS show that groundwater moving in the saturated zone beneath Yucca Mountain is the result of recharge from precipitation falling locally and in areas upgradient from the site. The data also show that much of the recharge to this underground reservoir probably happened tens of thousands of years ago in this region.

7.5.3.2 (11103)
Comment - EIS002135 / 0009
This DEIS fails to adequately address the seismic and hydrology issues of Yucca Mountain. Five years ago, the DOE was saying that there was no water flow through the mountain and there was no sustained movement in the ground, but now it's been proven that there is a lot of water migration through the mountain and that the mountain is indeed moving, as the Western Shoshone have claimed all along.

Response
DOE has conducted an extensive program to characterize the seismic hazards in the Yucca Mountain region (see Section 3.1.3.3 of the EIS for details). Using seismic hazard information gathered from this program, surface facilities at the repository that are important to safety would be designed to withstand ground motion from a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain and from a magnitude 7.5 earthquake or greater in Death Valley within 50 kilometers (31 miles) of Yucca Mountain.

Subsurface facilities would be built in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have less an effect on subsurface facilities than surface facilities. Inspection of existing tunnels in the Yucca Mountain area has revealed little evidence of disturbance after earthquakes. The subsurface facilities would be designed to withstand the effects of earthquakes during the long postclosure period (thousands to tens of thousands of years).

With regard to groundwater, DOE has conducted an extensive program to characterize the hydrology of Yucca Mountain and its relationship to the regional hydrologic system (see Sections 3.1.4.2.2 and 5.4 of the EIS for details). Extensive studies conducted at Yucca Mountain show evidence of low rates of water infiltration and percolation, long groundwater residence times, and a repository horizon that has been hydrologically stable for long periods of time. The waste emplacement areas are away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release. Additional fault movements or displacements from postemplacement seismic activity would probably be along existing fault planes.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for additional information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for additional information).

7.5.3.2 (11268)
Comment - EIS001814 / 0003
[Sections] 4.1.3 to 4.1.3.3 Effects on Water Resources

The DEIS consistently underestimates the potential of leaching from the site to adversely impact surface and groundwater in the region. The site drains into the Amargosa River system which drains an area of 3,100 square miles. The area encompassed by these water resources includes Death Valley National Monument as well as many small and growing communities in Nevada and California: Tecopa Springs, Pahrump and Amargosa Valley. Furthermore, the area is subject to flash flooding and volcanic activity which can alter the water courses in unexpected ways. The DEIS minimizes the possibility of high rainfall events and assumes that the meteorology in the area will remain stable for centuries. Such absurd assumptions cannot be used as the basis for a purportedly scientific assessment of the risks to water resources.

Response
Section I.2.2 of the EIS discusses future climates. One of the basic premises of Total System Performance Assessment is that the climate over the next 100,000 years will be considerably wetter than the current climate of Yucca Mountain. DOE built this assumption of wetter conditions into models that simulated infiltration and flux in the unsaturated zone and recharge to, and flow and transport of contaminants in, the saturated zone. These submodels feed into the Total System Performance Assessment to predict the exposure of individuals to radionuclides at specific distances from the repository and at specific future times.

DOE believes Chapter 5 of the EIS and the cited references treat this issue in a balanced fashion, and that further explanation is unnecessary.

7.5.3.2 (11269)
Comment - EIS001814 / 0004
The DEIS sections on the environmental consequences of construction, operation and closure of the proposed facility fail to acknowledge the potential impacts to water resources. Rather, the DEIS assumes that any and all

accidental releases of radioactive waste will be contained immediately and cleaned up promptly throughout the lifetime of the project. Such an assumption defies reality. Further, this renders the DEIS internally inconsistent in that the assessment of potential environmental consequences over the long-term acknowledges that impacts on water will be the dominant impacts. See [Section] 5.10 at [page] 5-49.

Response
The EIS discusses radiological accidents during three phases of the project. Chapter 4 concerns the active phase of the project, when radioactive waste is processed at the surface and placed in the subsurface. DOE does not assume that accidental release of radioactive waste would be contained immediately and cleaned up promptly without consequences. Section 4.1.3.2 specifically discusses the potential for the spread of contaminants to surface waters and Section 4.1.3.3 discusses the potential for the spread of contaminants to groundwater. Furthermore, Section 4.1.8 discusses the impacts from potential accidents during the preclosure period and estimates dose rates to both onsite and offsite populations from a variety of accidents. Appendix H of the EIS contains a detailed description of accident scenarios and consequences, including the analytical methods used to evaluate the accidents.

Section 6.2.4 of the EIS describes accident scenarios during transport of radioactive waste to the repository and described in greater detail in Section J.1.4.

Finally, Chapter 5 of the EIS addresses the environmental consequences of long-term repository performance after closure. Section 5.4 examines waterborne radiological consequences of the repository. This section discusses that over thousands of years the repository would leak small amounts radioactive contaminants, which would then be transported in groundwater to the Amargosa Desert where people could be exposed to radioactivity through the use of this groundwater. Doses to individuals are presented, as well as the risk of contracting fatal cancers. Appendix I contains supporting information on long-term consequences.

In summary, the EIS acknowledges and describes the consequences to water resources from releases of radioactive materials from the repository. The consequences of accidents during the transportation of waste to the proposed repository and during the preclosure phase of the repository would be minimized through the use of controls, monitoring, spill response plans and procedures, and regulatory requirements. Chapter 5 of the EIS discusses that the groundwater downgradient from the repository would be contaminated to some extent due to releases from the repository over the long term (thousands to millions of years after closure). However, DOE believes that the combination of natural and engineered barriers at Yucca Mountain would keep such releases well below the radiation-protection standards at 40 CFR Part 197.

7.5.3.2 (11412)
Comment - EIS002251 / 0010
We have 27 active volcanos that you can see from the top of Yucca Mountain. You may not think they are active, but the Shoshone people, since the 1900's have seen two volcanos erupt there. They have a lot of historic knowledge and we haven't been around long enough. We know now there's 33 earthquake faults, and they have yet to really be consulted with the history around Yucca Mountain and the fact that there have been these recent eruptions -- there's hot springs in the area, which we know the mineral waters migrate; they aren't stable like cool water springs might tend to be.

The people that drilled the Yucca Mountain exploratory hole, quote, said that it is the worst possible material that you could go in. If you go down the hole, you will see areas where the rock is fractured not much bigger than a two-inch gravel, being held back by iron I-beams. And it's like how are you expecting with all of this heat from radioactive waste to keep it from affecting the iron and allowing for a cave-in?

Response
There is no geologic evidence of eruptions from volcanoes in the Yucca Mountain vicinity since the 1900s. Based on extensive research, there are no warm springs in the immediate vicinity of Yucca Mountain. The closest warm springs to Yucca Mountain are at Beatty, 20 kilometers (12 miles) west of the site. Warm springs in the Amargosa Desert to the south are nearly 50 kilometers (31 miles) from the site, although there are warm-water wells about 20 kilometers to the south (DIRS 112530-Flynn et al. 1996).

This comment implies that faults at the site are pathways for hot spring deposits. Flynn et al. (DIRS 112530-1996) conducted a literature review to identify any mention of siliceous or calcareous spring deposits within 80 kilometers (50 miles) of the Yucca Mountain site. Such deposits are indicators of past or present hot-water systems with subsurface temperatures of more than 180°C (356°F). There is no evidence to suggest that thermal fluids have discharged at the surface during the Quaternary Period (the last 1.6 million years).

Data from drilling and excavation of the Exploratory Studies Facility do not support the comment's contentions regarding rock mass characteristics. DOE has not used extensive underground supports throughout the Exploratory Studies Facility, but only where the rock is fractured by closely spaced joints (particularly along portions of the north and south ramps). Ongoing thermal mechanical testing in the Exploratory Studies Facility will provide data that the Department can use as input to repository design. DOE does not anticipate that the heat generated by the waste would affect the integrity of the walls and ceilings of the waste emplacement drifts.

7.5.3.2 (11665)
Comment - EIS000044 / 0001
I am the author of two documents cited in the Yucca Mountain Draft Environmental Impact Statement. Copies of this report are available on the Yucca Mountain home page and portions of these reports have been quoted, and misquoted, in the Draft EIS.

Response
DOE cited the documents referred to by the commenter four times in the EIS, three times in Section 3.1.11.1 and once in Section 4.1.3.3. DOE evaluated information from many sources while compiling the EIS. In considering this comment, the Department verified that the citations in Section 3.1.11.1 to Buqo (DIRS 101542-1996) are accurate and supported by the text. The first citation refers to the purpose of the report as stated in its title. The second citation refers to the perennial yield of 19,000 acre-feet (about 23.4 million cubic meters) for the Pahrump Valley Basin. This quantity is in the table of water budget parameters as cited in the EIS.

DOE has corrected the citation in Section 3.1.11.1 of the EIS from "Buqo (1999, page 34)" to "Buqo (1999, p. 36)." In Section 4.1.3.3 of the EIS, DOE has corrected the citation from "(Buqo 1999, pages 37 and 51)" to "(Buqo 1999, pp. 37, 38, 52)."

7.5.3.2 (11737)
Comment - 010382 / 0001
This is to acknowledge receipt of recent materials referring to the draft environmental impact statement (EIS) for Yucca Mountain. Unfortunately, I was moving to a new job in Oklahoma and did not have time to respond. Your last flyer about the deadline on public comments reached me at my new address after the deadline. But I want to assure you that there is still plenty of opportunity for you to make it into the textbooks as the example of a program manager who allowed the credentials of those who gave him the answers he wanted to hear to trump the math that he did not.

If you refer to the following web site:

http://www.uark.edu/depts/agronomy/scott/research.html

you will find a set of draft papers that describe a new quasi-analytic exact solution to Richards' equation for unsaturated flow. Saying that it is a "general" solution is my mistake, not Dr. Scott's. The approach only works for inflow wetting fronts that are monotonic in space. Nevertheless, it works for a variety of boundary conditions, including constant head and constant inflow in both the horizontal and vertical.

You may recall that Drs. Liu and Bodvarsson claimed that the circumstance of constant vertical inflow demonstrated my work to be non-physical and invalid. Funny thing about that -- the draft papers include a comparison of the vertical constant inflow exact solution to a finite difference model using one of my approaches to Darcian intergrid conductivity means. The agreement is quite good, and can easily be verified by anyone with a sufficient background in graduate-level math. As for my work being physically invalid, it is as physically valid as any exercise in applied math can be. My math does not become non-physical just because I did not seek the almighty permission of your domestic reviewers to get it right. It does not become invalid just because you apparently have neither the background nor the will to challenge your reviewers on the math. It does not become inapplicable just because it may thwart some of the forgone conclusions of the Nuclear Club.

Response
For more than two decades, DOE, along with other Federal agencies, has conducted a rigorous evaluation of the suitability of Yucca Mountain for a geologic repository. During this period, the Department's efforts have been periodically reviewed by the Nuclear Waste Technical Review Board, the National Academy of Sciences and, most recently, the public during the EIS process. The Department appreciates the views and interest of the commenter on this national program.

7.5.3.2 (11745)
Comment - EIS002299 / 0003
In 1989, California's Interagency High-Level Waste Task Force, coordinated on by the California Energy Commission, provided comments on DOE's Site Characterization Plan regarding its adequacy for evaluating potential groundwater impacts in California from the proposed Yucca Mountain project. We identified as a major concern the potential migration of radionuclide contaminants into eastern California aquifers, including the Death Valley groundwater basin, resulting from an accidental radionuclide release at the Yucca Mountain site. We also recommended scientific analyses that were necessary to help evaluate such potential impacts. However, the Draft EIS does not reflect California's recommendations for evaluating these potential groundwater impacts from the proposed repository. We consider the inadequacies of the Draft EIS's discussion and analyses regarding potential groundwater impacts in California to be seriously deficient.

Response
Section 3.1.4.2.1 of the EIS shows that the flow of groundwater from Yucca Mountain is south toward Jackass Flats and the Amargosa Desert, and continues southward to the primary point of discharge at Franklin Lake Playa in Alkali Flat. The EIS recognizes that some groundwater reaching this far might bypass Franklin Lake Playa and continue southward as underflow beneath the channel of the Amargosa River toward surface discharge areas in the channel near Tecopa, California, about 42 kilometers (26 miles) south of Alkali Flat.

In addition, the EIS acknowledges that a fraction of the groundwater flow beneath the Amargosa Desert may flow through the southeastern end of the Funeral Mountains toward spring discharge points in the Furnace Creek Wash area of Death Valley. Several large springs (Texas, Travertine, and Nevares) discharge about 4 million cubic meters (3,250 acre-feet) per year near Furnace Creek Ranch on the east side of Death Valley. It is generally accepted that this spring flow exceeds local recharge and that the water from beneath the Amargosa Desert contributes to the flow. Geochemical, isotopic, and temperature data indicate that water discharging from springs in the Furnace Creek area is a mixture of water from basin-fill aquifers in the northwestern Amargosa Desert and deeper flow in the regional carbonate aquifer (DIRS 101167-Winograd and Thordarson 1975). The groundwater in the northwestern Amargosa Desert originates in the Amargosa River drainage in Oasis Valley and from the eastern slope of the Funeral Mountains, both of which are west of the flowpaths that extend southward from the Yucca Mountain repository area. Even if part of the flow from Yucca Mountain mixes into the carbonate pathway that supplies the Furnace Creek springs, it is too little to noticeably affect the springflow chemistry. Considering the small fraction of water that would infiltrate though the repository (approximately 0.2 percent or less), compared to total amount of water flowing through the basin, and considering the large distances involved [more than 60 kilometers (37 miles) from the source], any component of the flow from Yucca Mountain would be diluted to such an extent that it would be undetectable.

As described in Section 3.1.4 of the EIS, the Death Valley regional groundwater flow system is a terminal hydrologic basin. That is, there is no natural pathway for water (groundwater or surface water) to leave the basin other than by evaporation or transpiration through plants. Death Valley is the low point in the hydrologic basin. A primary focus of the EIS is the evaluation of potential groundwater impacts along this flow path. Chapter 5 of the EIS summarizes the modeling of the long-term performance of the repository. The results show that the combination of natural and engineered barriers at Yucca Mountain would keep doses resulting from such releases well below the regulatory limits established at 40 CFR Part 197.

The farthest distance evaluated in the EIS is at Alkali Flat because that is as far as most of the flow travels. However, it can be clearly seen in the evaluation in Chapter 5 that risks would decrease with increasing distance from the repository. Accordingly, potential impacts to locations beyond Alkali Flat, because they would be farther away on the groundwater flow path, would be less than those for the furthest distance evaluated in the EIS (Alkali Flat). See Appendix I of the EIS and the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) for additional information.

7.5.3.2 (11935)

Comment - EIS001107 / 0003

The Draft EIS fails to address whether the groundwater in the Franklin Lake Playa and Death Valley areas could migrate to other aquifers in the region. Death Valley is clearly the lowest point in the area, but evidence collected by the Department of Energy (DOE) and presented in the Draft EIS suggests that due to differences in underground pressure water can ingrate upwards. Considering the important of water supplies to both humans and the environment region, much more specific information regarding the ground water flow is necessary before the geologic repository can be recommended. The lack of such information makes it difficult to comment on the Draft EIS because the risks are not clear.

Response

DOE has conducted an extensive site characterization program to evaluate the suitability of Yucca Mountain as the site for the proposed repository. Through this characterization program, DOE has gained valuable knowledge of the flow system in the saturated and unsaturated zones. DOE recognizes that additional data would further define and reduce uncertainty regarding the interactions of the alluvial, volcanic, and carbonate aquifers in the saturated zone.

To establish more confidence in its understanding of the regional and site-scale flow systems, DOE has supported Nye County with development of it's Early Warning Drilling Program. Information from a performance confirmation program (if the site was recommended and approved), could be used in conjunction with that from the Early Warning Drilling Program to refine the DOE understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information, which is described in Section 3.1.4.2.1 of the EIS.

Groundwater beneath Yucca Mountain is part of the Death Valley Regional Groundwater Flow System. As described in Section 3.1.4 of the EIS, Death Valley is a terminal hydrologic basin; that is, there are no natural pathways for groundwater or surface water to leave the basin other than by evaporation or transpiration through plants. The routes and pathways through which the basin's groundwater moves are complex. There are places where several aquifers are on top of one another, and water moves up or down based on the relative pressures in the aquifers. There are also places where water moves horizontally as one aquifer pinches out and another becomes the flow path. These complexities make it very difficult, if not impossible, to know each and every path in the regional flow system. However, there is little uncertainty that the general direction of groundwater flow in the regional system is to the south. Groundwater flows toward Death Valley unless it is removed from the system by evaporation or transpiration, or by man (for example, by pumping).

The general path of the water that percolates through Yucca Mountain is south toward Amargosa Valley, into and through the area around Death Valley Junction and lower Amargosa Valley. Groundwater from beneath Yucca Mountain merges and mixes with underflow from Fortymile Wash and then flows and mixes into the very large groundwater reservoir in the Amargosa Desert, where it is expected to move slowly due to the high effective porosity of the basin deposits in the Amargosa Desert. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa, an area of extensive evapotranspiration, although a minor volume might flow south toward Tecopa into southern Death Valley. A small amount of the groundwater might flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains and discharge at springs near Furnace Creek in Death Valley. Sparse potentiometric data indicate that a divide could exist in the Funeral Mountains between the Amargosa Desert and Death Valley. Such a divide would limit discharge from the shallow flow system, but not necessarily affect the deeper carbonate flow system that also could contribute discharge to the Furnace Creek area (DIRS 100465-Luckey et al. 1996). Geochemical, isotopic, and temperature data indicate that water discharging from springs in the Furnace Creek area is a mixture of water from basin-fill aquifers in the northwestern Amargosa Desert and the deeper water in the regional carbonate aquifer (DIRS 101167-Winograd and Thordarson 1975). Groundwater in the northwestern Amargosa Desert originates in the Amargosa River drainage in Oasis Valley and from the eastern slope of the Funeral Mountains, both of which are west of the flow paths that extend southward from Yucca Mountain. Even if part of the flow from Yucca Mountain also mixes into the carbonate pathway that supplies the Furnace Creek springs, it is too little to noticeably affect the springflow chemistry. Considering the small fraction of water that would infiltrate though the repository footprint (approximately 0.2 percent or less) compared to the total amount of water flowing through the basin and the large distances involved [more than 60 kilometers (37 miles) from the source], any component of the flow from Yucca Mountain that flowed in this very long and complicated path would be diluted to such an extent that it would be undetectable.

7.5.3.2 (12132)
Comment - EIS001887 / 0433
The distribution of infiltration across the Yucca Mountain block is questioned. The distribution of infiltration used in the DEIS is highest at the crest. There are indicators which would suggest that peak infiltration is on the western flank of the mountain block. Infiltration in this western block region may be underestimated and its effect unknown.

Response
The infiltration maps of Yucca Mountain were prepared using data from a combination of weather stations, precipitation gauges, soil type/thickness maps, and an extensive network of neutron boreholes. The neutron boreholes are located wherever reasonable access for borehole drill rigs supported the installation of such instrumentation. Due to the steepness of the western flank of Yucca Mountain, installation of boreholes was not attempted. Section 3.1.4.2.1 of the EIS and the references cited in that section contain additional information about water infiltration at Yucca Mountain.

Investigations of the potential for the western side of Yucca Mountain to have significant infiltration are being addressed through activities in the cross-drift. The portion of the cross-drift that underlies the possible high-infiltration zone under the crest of the mountain, and areas under the steep western flank, has been isolated behind dual-bulkheads. The objective of such isolation (that is, free from the influence of tunnel ventilation) is to measure any natural infiltration. These activities will determine whether the present infiltration map of Yucca Mountain requires any modification.

7.5.3.2 (12139)
Comment - EIS001887 / 0431
As we commented on the VA [Viability Assessment], there are serious concerns about the selection of groundwater pathway and its associated hydrologic and geochemical parameters used for compliance assessments. As stated earlier there has been considerable debate over the actual flow paths which would be followed by the radionuclides released from the repository. We most likely have several different groundwater pathways for radionuclide travel and several differing populations to consider in the compliance determination, i.e., Lathrop Wells and Amargosa Valley. These flow path directions range from approximately 90º to 180º south, roughly. The flow pathways are complicated to model accurately, because they are diverse, chemically and hydrologically and could be significantly different in terms of calculating radionuclide transport via the groundwater and concentrations at a given point. Further, EPA [Environmental Protection Agency] has not defined the Critical Group or receptor as yet.

Response
DOE has conducted extensive studies of the saturated and unsaturated zones at Yucca Mountain. But, as pointed out by the commenter and the EIS, the groundwater system in the Death Valley region is very complex and there are areas of uncertainty with respect to its characterization. As with the study of most natural systems, it is simply not possible to know everything. The Department recognizes that the acquisition of additional data would reduce the uncertainty regarding some aspects of the long-term performance of the repository, but also recognizes that some uncertainty is inherent to the process. The approach used by DOE to assess the long-term performance of the repository (summarized in Chapter 5 of the EIS) was to recognize the uncertainties that are important to the assessment and to identify which of these uncertainties could be minimized with additional data and which could not. With respect to those uncertainties that are the result of a data gap, DOE made conservative assumptions where necessary, realizing that information gained from ongoing studies may eventually support less conservative assumptions and less conservative estimates of impacts. The approach for dealing with the uncertainties of long-term performance of the repository is discussed more fully in Section 5.2.4 of the EIS.

DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

Regarding the significance of the flow path in modeling the performance of the repository, Chapter 5 of the EIS explains that because groundwater would be the primary mechanism of contaminant transport, the impacts would be along the groundwater flow path downgradient of the repository. Accordingly, the direction of flow is very important in the model. The best available information indicates that the direction of flow is toward the community of Amargosa Valley (formerly known as Lathrop Wells) at about 20 kilometers (12 miles) of the repository site. If a different groundwater flow path were to be assumed, groundwater (and contaminants) would have to travel further to reach a populated area and, accordingly, projected risks to inhabitants of the area would go down. In other words, the groundwater flow direction used in the performance assessment model maximizes the estimated impacts to nearby populations.

The analysis of long-term repository performance contained in the Final EIS is somewhat different than what was described in the Draft EIS. Under direction of the Nuclear Waste Policy Act, as amended (42 U.S.C. 10101 *et seq.*), the Environmental Protection Agency and Nuclear Regulatory Commission are directed to develop standards for the performance of the Yucca Mountain Repository. The analysis in the Final EIS conforms to the final requirements set by the Environmental Protection Agency (40 CFR Part 197). These standards would be used to judge the performance of the repository as part of the Nuclear Regulatory Commission licensing process. The Final EIS includes an individual exposure scenario for the repository as required in 40 CFR Part 197. Under 40 CFR Part 197, an exposed individual is designated as one living at a point of maximum contaminant concentration 18 kilometers (11 miles) from the repository. This person would have a diet and living style representative of people now living in Amargosa Valley, Nevada, and would drink 2 liters of water per day from wells tapping the groundwater at the person's place of residence. The Final EIS (Chapter 5) also addresses a groundwater protection standard established in 40 CFR Part 197. In this case though, specific water standards are to be met by a segment of groundwater identified by volume (that would be used annually by a hypothetical community) and location (with respect to the groundwater flow path from Yucca Mountain) by the regulation. Based on these new standards, the direction of the groundwater flow path has little impact on the ability to show compliance with the Environmental Protection Agency standards because the standards are based on a critical distance from the repository where the contaminant concentrations would be highest (that is, along the flow path, whatever its direction).

7.5.3.2 (12313)
Comment - EIS001521 / 0063
Page 3-52, second paragraph--(Water Source and Movement) Reference the tectonic event and water-table slope figures. Also, water-table gradients are big, small, huge, tiny, and large, etc., but never "steep" as stated. Again, the potentiometric surface discussion in this paragraph, on the rest of this page, and on page 3-53 would be greatly enhanced by showing a simple potentiometric-surface map. The reader could see the described features instead of trying to figure out where they are located by textual descriptions.

Response
DOE has added a figure to this section of Chapter 3 of the EIS to show the estimated potentiometric surface of the Death Valley region.

In response to this comment, DOE has changed the term "steep gradient" to "large gradient."

7.5.3.2 (12314)
Comment - EIS001521 / 0076
Page 4-28, second paragraph--Why introduce a water-level-decline value here (12 centimeters) that was not used in the section 3.1.4.2.2, Ground Water at Yucca Mountain discussion? The maximum decrease discussed on page 3-56, Table 3-16, and in related text was 6 centimeters (calculated below the average deviation about the median). Numbers related to water level declines and/or increases should be consistent throughout the DEIS.

Response
The maximum water-level decrease cited is not inconsistent with Table 3-17, which shows a 12-centimeter (4.7-inch) difference at well J-13. The 6-centimeter (2.4-inch) difference referred to in the last bullet on page 3-56 of the Draft EIS is 6 centimeters below the normal ± 6-centimeter average deviation for well J-13, hence a total of 12 centimeters. Because this caused confusion, DOE has changed the text in Section 4.1.3.3 to show a range of 6 to 12 centimeters, so a comparison to Table 3-17 can indicate that the range of elevation decrease does or does not consider the average deviation.

7.5.3.2 (12402)
Comment - EIS001887 / 0165
Page 3-39; Section 3.1.4.2.1 - Regional Groundwater

The distribution of infiltration across the Yucca Mountain block is questioned. The distribution of infiltration used in the Draft EIS is highest at the crest. There are indicators which would suggest that peak infiltration is on the western flank of the mountain block. Infiltration in this western block region may be underestimated and its effect unknown.

Response
DOE used data from a combination of weather stations, precipitation gauges, soil type/thickness maps, and an extensive network of neutron boreholes to prepare the estimates of infiltration at Yucca Mountain in Section 3.1.4.2.1 of the EIS. DOE placed the neutron boreholes wherever reasonable access for borehole drill rigs supported the installation of such instrumentation. Due to the steepness of the western flank of Yucca Mountain, installation of boreholes was not attempted.

Investigations of the potential for the western side of Yucca Mountain to have significant infiltration are being addressed through activities in the cross-drift. The portion of the cross-drift that underlies the possible high-infiltration zone under the crest of the mountain, and areas under the steep western flank, have been isolated behind dual bulkheads. The objective of such isolation (that is, free from the influence of tunnel ventilation) is to measure natural infiltration. These activities will determine whether the present infiltration map of Yucca Mountain requires modification.

7.5.3.2 (12406)
Comment - EIS002299 / 0006
Inyo County, California, testified before DOE regarding the long-term threat that the Yucca Mountain repository poses to regional groundwater supplies and to communities east of Owens Valley. They noted that hydrologic studies conducted by Inyo County and Nye and Esmeralda Counties in Nevada point to the existence of a continuous aquifer running from beneath Yucca Mountain south to Tecopa, Shoshone and Death Valley Junction. These studies indicate that water flowing beneath Yucca Mountain flows generally south to become surface water and groundwater flowing into Death Valley that is used for commercial and domestic purposes and supports natural habitats. Some of these springs also support populations of a number of threatened or endangered species.

California agencies concluded that DOE should more fully evaluate potential pathways for radionuclides reaching regional groundwater supplies in eastern California, such as in the Death Valley region. The EIS should also evaluate the effect of DOE's proposed groundwater extraction in Jackass Flats on the flow of groundwater to discharge areas of the regional aquifer in California. DOE's proposed groundwater extraction at Jackass Flats will decrease the amount of water that flows through the aquifer and is discharged at down-gradient springs and wetlands. Better data and more realistic models are needed to evaluate groundwater flow and radionuclide migration toward California aquifers. In addition, DOE needs to describe how they will monitor or detect migration of radionuclides from the repository.

Proposed Yucca Mountain design considers the possibility of radionuclide containment failure, and incorporates engineered barriers, as well as reliance on natural barriers to mitigate the consequence of radionuclide leakage. We agree that the possibility of failure should be considered in the repository design, and in the evaluation of potential environmental consequences. However, additional data coupled with more realistic models of radionuclide migration are needed to make an adequate determination on potential impacts. Further, the Draft EIS does not describe future monitoring of groundwater flow with the goal of detecting any migration of radionuclides from the repository. Similar to the status of groundwater transport modeling, there is very limited data that supports only elementary models of barrier performance. These give rise to significant uncertainties regarding long-term performance of each barrier to radionuclide contamination. The degree of scientific uncertainty surrounding the repository appears to be too high to support a reasonable decision on the adequacy of the Yucca Mountain site. These uncertainties include: 1) the corrosion rate of waste packages, 2) disagreement on groundwater levels and aquifer conductivity estimates, 3) the influence of heat on water movement, 4) differing opinions about the solubility and release of radionuclides into the environment, and 5) uncertainty regarding water seepage through the walls of the repository.

Response
DOE recognizes that the groundwater flow path from Yucca Mountain includes the locations identified by the commenter, with the exception of the Owens Valley area. Section 3.1.4.2.1 of the EIS indicates that the primary discharge point for groundwater flowing beneath Yucca Mountain is Franklin Lake Playa in Alkali Flat. The EIS also recognizes that a small amount of groundwater reaching this far might bypass Franklin Lake Playa flow south toward Tecopa, California. A fraction of the groundwater may also flow through fractures in the relatively impermeable Precambrian rocks in the southeastern end of the Funeral Mountains toward spring discharge points in Furnace Creek area of Death Valley. Several large springs (Texas, Travertine, and Nevares) in the Furnace Creek Wash area of Death Valley discharge about 4 million cubic meters (3,250 acre-feet) per year near Furnace Creek Ranch on the east side of Death Valley. This springflow exceeds the local recharge, and the water from beneath the Amargosa Desert contributes to the flow. Sparse potentiometric data indicate that a divide could exist in the Funeral Mountains between the Amargosa Desert and Death Valley. Such a divide would limit discharge from the shallow flow system, but not necessarily affect the deeper carbonate flow system that also may contribute discharge to the Furnace Creek area (DIRS 100465-Luckey et al. 1996). Geochemical, isotopic, and temperature data indicate that water discharging from springs in the Furnace Creek area is a mixture of water from basin-fill aquifers in the northwestern Amargosa Desert and the deeper water in the regional carbonate aquifer (DIRS 101167-Winograd and Thordarson 1975). Groundwater in the northwestern Amargosa Desert originates in the Amargosa River drainage in Oasis Valley and from the eastern slope of the Funeral Mountains, both of which are west of the flow paths that

extend southward from Yucca Mountain. Even if part of the flow from Yucca Mountain also mixes into the carbonate pathway that supplies the Furnace Creek springs, it is too little to noticeably affect the springflow chemistry. Considering the small fraction of water that would infiltrate though the repository (approximately 0.2 percent or less), compared to total amount of water flowing through the basin, and considering the large distances involved [more than 60 kilometers (37 miles) from the source], any component of flow from Yucca Mountain that traveled in this long and complicated path would be diluted to such an extent that it would be undetectable.

Chapter 5 of the EIS does not specifically address risks in Death Valley National Park from the use and consumption of groundwater. However, the evaluation in Chapter 5 clearly indicates that risks would decrease with increasing distance from the repository. For all closer areas that were examined, modeling of the long-term performance of the repository shows that the combination of natural and engineered barriers at Yucca Mountain would keep doses resulting from any releases of radioactive materials within the regulatory limits established by the Environmental Protection Agency in 40 CFR Part 197.

Section 5.9 of the EIS addresses impacts to biological resources during the long-term performance of the repository. As indicated in that section, DOE did not quantify impacts to biological resources from exposures to contaminated groundwater, but related them instead to the minimal impacts likely for humans through the use and consumption of groundwater. Section 3.1.4 of the EIS describes the Death Valley groundwater flow system as a terminal hydrologic basin. That is, there is no natural pathway for water (groundwater or surface water) to leave the basin other than by evaporation or transpiration through plants; Death Valley is the lowest part for the basin. With this in mind, impacts to groundwater in the area east of Owens Valley from the repository would be unlikely. Depending on the specific location of concern, groundwater in Owens Valley would be either outside the Death Valley groundwater flow system (DIRS 100131-D'Agnese et al. 1997), or the groundwater flows toward the Death Valley groundwater flow system. That is, groundwater from Yucca Mountain would have to flow down to Death Valley and then back upgradient to reach areas east of Owens Valley that are outside the Park.

Section 4.1.3 of the EIS addresses the short-term impacts from the extraction of groundwater for construction, operation and monitoring, and closure of the repository. It considers these impacts to be short-term compared to those impacts dealing with the long-term, postclosure performance of the repository discussed in Chapter 5. Section 4.1.3.3 states that groundwater withdrawals at Jackass Flats would, to some extent, reduce the amount of underflow that would reach downgradient areas. However, Section 4.1.3.3 also states that the area first experiencing such an impact would be the Amargosa Desert, and the amount of water required by repository activities would be very small compared to the amount of groundwater already being withdrawn in the Amargosa Desert.

As a result of the monitoring concerns expressed by many commenters, DOE has supported Nye County with it's program (called the *Early Warning Drilling Program*) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the performance confirmation program (if the site is approved for a repository), could be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information, which DOE has incorporated in the EIS in Section 3.1.4.2.1.

Chapter 5 of the EIS describes how DOE modeled the movement of contaminants potentially released from the slow degradation of waste packages in the repository. The model incorporated the slow movement of water in the rock matrix and the relatively fast movement of water along rock fractures and faults. Although the rate at which groundwater moves is important to the model, it is not the only factor that controls the movement of contaminants. Section I.2.4 describes how DOE modeled waste package degradation and how the cladding and waste form degradation models come into play before the contaminants would become available for transport through the unsaturated zone and eventually the saturated zone. It also describes the mechanisms that would affect how these materials would move through the zones, including movement with colloids and the sorption and desorption that would occur as individual radionuclide or chemical species interacted with the rock through which they were moving. The performance assessment model includes these and other parameters in the estimate of impacts to the groundwater and downgradient users of that groundwater.

DOE has conducted extensive studies of the saturated and unsaturated zones at Yucca Mountain. The Department recognizes that the acquisition of additional data would reduce the uncertainty regarding some aspects of the long-term performance of the repository, but also recognizes that some uncertainty is inherent to the process. Section 5.2.4 discusses how DOE dealt with uncertainties concerning evaluations of the long-term performance of the repository. The same section addresses variability issues (as opposed to uncertainties) associated with the natural features of the system being modeled. It describes the techniques, such as sensitivity analysis, used in the modeling effort to analyze various parameter uncertainties and variabilities and to gauge their effects on modeling results. In summary, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.
2. Consideration of features, events and processes that could affect repository performance over the long-term.
3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.
4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.
5. Parameter distributions that represent the possible change of the system over the long term.
6. Use of conservative assessments that lead to an overestimation of impacts.
7. Performance of sensitivity analyses.
8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3.2 (12517)
Comment - EIS000029 / 0001
How can you draft an impact statement when you haven't accounted for all the modeling errors?

Recent work (publications and draft papers on www.aquarien.com) in numerical methods for modeling the vertical unsaturated flow of water in porous media has uncovered previously unrecognized errors in standard methods. These errors may affect the validity and reliability of models that attempt to predict the flow of water and the transport of hazardous and nuclear waste on the scale of tens to thousands of years. The following questions and three-point grid test demonstrate how the common arithmetic mean of intergrid unsaturated hydraulic conductivity violates Darcy's law for vertical unsaturated flow in all but a few trivial conditions, and can even violate the mathematical minimum-maximum principle for elliptic boundary value problems (steady-state flow problems). By contrast, a Darcian intergrid conductivity mean for the exponential pressure-conductivity relation solves such problems perfectly. The numerical examples in the appendix compare parallel models of a relaxing wet pulse in a long, vertical fracture, using the exponential pressure-conductivity relation. One model uses the arithmetic mean, and the other the analytic Darcian mean, with exactly the same adaptive time steps for both. The arithmetic mean model exhibits a dry spike that grows with the logarithm of time, and oscillations similar to numerical dispersion, both associated with space steps where the arithmetic mean can violate the min-max principle. By contrast, the Darcian mean model is smooth and well-behaved.

[Comment included a detailed analytical discussion of modeling methodologies.]

Response
Because conductivity is a function of pressure and saturation, and because saturation and pressure may vary between adjacent nodes or elements, then one must use some average of the conductivities of adjacent elements in a model to calculate the flow between those elements. Warrick (DIRS 155154-1991) and more recently Baker, Arnold, and Scott (DIRS 155155-1999) pointed out that some choices for averaging methods can produce erroneous results, especially arithmetic averages. DOE's unsaturated flow codes do not use arithmetic averages nor most of the averaging methods Baker describes. As discussed in Pruess (DIRS 100413-1991) and Oldenburg and Pruess (DIRS 141594-1993) the appropriate method to use is upstream weighting though specific conditions such as capillary barriers may warrant other choices. Baker, Arnold, and Scott (DIRS 155155-1999) developed methods to resolve the averaging issue, though he points out that upstream weighting does not produce the same errors as most other averaging methods and is efficient computationally. Averaging problems are most severe when the model uses constant pressure conditions between nodes, and there are large pressure differences between adjacent nodes or elements. The unsaturated zone modeling is performed under conditions of specified infiltration rate (fixed-flux, hence flow errors cannot be greater than the fixed flux value), and fine discretization of regions of high-pressure change to mitigate the potential averaging problems. The use of these conditions along with upstream weighting is sufficient to ensure acceptable accuracy in the unsaturated zone simulations.

In summary, DOE has evaluated a wide range of modeling methods and believes that the modeling methods selected are appropriate for long-term performance analyses.

7.5.3.2 (12615)
Comment - EIS001816 / 0001
Section 3.1.4 Hydrology: description of the current system of groundwater flow in the Death Valley region is inadequate at this time because it is based largely on the oversized, data sparse, regional flow model. This model is presently being redone and adjusted to make use of new and ongoing data collection. The understanding of the lower carbonate aquifer hydraulic relationship to overlying volcanic and alluvial units beneath and down gradient of YM is inadequate and necessitates more than a single well test to define the transmissivity of this important, regional unit. The DEIS must do further analysis to determine what information will be collected and analyzed to more completely characterize the hydrologic character and structure of the carbonate aquifer system in the area of the repository footprint.

There is an inadequate to lack of a description of the hydraulic character and sorptive capability for radionuclides in the alluvial units in Fortymile Wash based on actual field data. More information is required and must be collected to determine the ability of this part of the natural barrier system to retard radionuclide migration.

Apparent hydraulic conductivity measurements are not very reliable on a large scale. Until the DOE can perform more hydraulic analysis of units in the vicinity of the repository footprint and downgradient based on multiple well drawdown tests with a pumping well and a monitor well, the apparent hydraulic conductivity values are inadequate. Apparent hydraulic conductivity values must be refined and the level of confidence greatly improved so that groundwater travel times in the repository area can be more reasonably estimated and technically defended.

Response
DOE continues to characterize the saturated alluvium and valley fill and carbonate aquifers south of the Yucca Mountain site. DOE has supported Nye County with it's program (called the Early Warning Drilling Program) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain, as well as the

relationships among the volcanic, alluvial, and carbonate aquifers. Information from the performance confirmation program (if Yucca Mountain is approved for a repository), could be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information (see Section 3.1.4.2.1 of the EIS).

In addition, DOE has installed a series of test wells along the groundwater flow path between the Yucca Mountain site and the Town of Amargosa Valley as part of an alluvial testing complex. The objective of this program is to better characterize the alluvial deposits beneath Fortymile Wash along the east side of Yucca Mountain. Single- and multi-well tracer tests have begun and the results thus far have strengthened the basis of the site-scale saturated flow and transport model. Information from this program has been incorporated in the EIS.

DOE realizes that the data obtained from the Nye County Early Warning Drilling Program are important to an understanding of the saturated zone system and performance assessment calculations south of Yucca Mountain. All data obtained from this program would be used to the extent possible for the enhancement of the saturated zone models. DOE scientists would perform sorption studies on lithologic material extracted from Nye County boreholes for incorporation into the saturated-zone transport model and abstraction into performance assessment calculations. Chemical data would enhance current studies on the understanding of saturated flow systems and various hydrochemical facies. Groundwater elevation data would continue to be determined from all wells and would be used to define flow and transport paths, calibrate models, and support the geologic framework model.

7.5.3.2 (13534)
Comment - 010390 / 0001
Although the S&ER provides detailed hydrogeologic information on the Yucca Mountain site, specific data on the hydrogeology of down-gradient areas is lacking. The final EIS should include any pertinent, hydrogeologic information obtained from the Nye County Early Warning Drilling Program.

More specifically, the hydrogeologic characterization of the carbonate aquifer in the vicinity of the Yucca Mountain repository is insufficient. The characterization, based on data from a single well, is not sufficient to provide a reliable interpretation of basic hydrogeologic parameters such as hydraulic conductivity and ground water flow direction. Further, it is recommended that additional monitoring wells be installed in the carbonate aquifer to further assess the hydraulic conditions within this aquifer, as well as to examine the hydraulic gradient between the volcanic and carbonate aquifers. Additional data would significantly improve the present hydrogeologic model and its ability to predict potential plume migration. The current computer models attempt to predict the fate and transport of radionuclides 10,000 years into the future. However, without an accurate representation of the present hydrogeologic parameters of the aquifer, it is difficult to judge the model's reliability.

Response
Since the Draft EIS was issued, a second well has penetrated the carbonate aquifer in Fortymile Wash (described further in Section 3.1.4.2.2 of the Final EIS). Similar to the first well, water in this second well had an upward hydraulic gradient. DOE nevertheless recognizes that additional information would refine DOE's understanding of the regional groundwater flow system and further reduce uncertainties. To provide additional information, DOE has supported Nye County with it's program (called the Early Warning Drilling Program) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain, as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the ongoing site characterization program and from the performance confirmation program (if Yucca Mountain is approved for a repository), would be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information (see Section 3.1.4.2.1 of the EIS).

If the Secretary recommends the site to the President, DOE would continue to implement a "performance confirmation program," elements of which would address the hydrologic system. The purpose of this program would be to evaluate the accuracy and adequacy of the information used to determine whether long-term performance objectives have been met. The performance confirmation program, which would continue through closure of the repository (possibly up to 300 years or more), would improve the understanding of the hydrologic system and reduce uncertainties.

7.5.3.3 Seismicity

7.5.3.3 (369)
Comment - EIS000045 / 0002
The draft EIS does not consider the risk of a major subterranean plate shift despite the very recent history of seismic activity. It only considers the actual movement of the ground at the site and the effect it will have on the processing facility and the canisters. The effect of a major plate shift on the water table was not considered. The last 20 years of history shows that the ability to predict such occurrences is not reliable. An example would be (within that 20 years) The earthquake near Arco, Idaho. The valley floor dropped 5 feet or more, water from the under ground aquifer sprang up as springs and lakes that never existed prior. Waverly Person, chief of the US Geological Survey's Earthquake Information Center, says "...There is no scientific way of predicting or forecasting." When speaking about earthquakes.

Response
DOE has maintained a network of water level monitoring boreholes in the area of the proposed repository site and the surrounding region since the early days of site characterization. Observations of water level elevation under normal conditions (that is, not transiently seismically influenced) indicate very minor changes (a few tenths of a meter) annually due to seasonal climatic variation in precipitation in this region. Several of the boreholes record water levels continuously or at short intervals (several times an hour), and thus have recorded the response of the water table to both local earthquakes (Little Skull Mountain, magnitude 5.6) and regional earthquakes (some as large as magnitude 7.3, such as the Landers, California, earthquake, on June 28, 1992) for almost two decades. In general, departures from long-term average water table elevation are minor, usually limited from a few centimeters to, at most, about 1 meter. These changes tend to be short-lived, with most monitored boreholes showing a return to pre-earthquake water levels within a few hours to a few days. In no instance has the network recorded any large permanent departures from pre-earthquake water levels.

DOE has gained additional confidence in this conclusion from other site characterization activities. Evidence from paleodischarge sites in the vicinity of Yucca Mountain and mineralogical data from deep boreholes at the site indicates that at no time in the geologic past has the regional water table been more than about 120 meters (390 feet) higher than it is at present. Given that the general elevation of the proposed repository would be at least 160 and up to 400 meters (520 up to 1,300 feet) above the present water table elevation, effects in response to earthquakes would be expected to be relatively minor and would not pose problems for repository safety.

7.5.3.3 (596)
Comment - EIS000127 / 0013
They consider earthquakes to be strong enough to completely demolish both the waste handling and the waste -- the other waste building that they plan on running the waste throughout there.

They figure both those buildings would collapse in an earthquake on top of the waste that's in 'em, and yet nothing is going to happen to a single one of those holes that they bored through that porous rock that's full of all those holes -- all these fissures per meter. It's not even considered at all.

Response
An extensive seismic hazard analysis was completed in 1998 involving 25 experts from industry, academia, and government. The expert assessments indicate that the geologic fault displacement hazard is generally low. Results of long-term performance assessments of the subsurface repository indicated no significant effects on waste isolation from earthquakes. The surface and underground facilities at Yucca Mountain are being designed to withstand ground motion from earthquakes. The analysis determined that an annual frequency of 1×10^{-4}, or the 10,000-year earthquake, is an appropriate level for preclosure design of structures that are important to safety. At Yucca Mountain, these structures will be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4}. For the 10,000-year earthquake, the design motions are dominated by the contribution of

a normal-fault type earthquakes of magnitude 6.3 with an epicenter within 5 kilometers (3 miles) of Yucca Mountain that respond to higher structural frequencies. At lower frequencies, contributions from strike-slip type earthquakes of magnitude 7.5 or greater events in Death Valley [within 50 kilometers (31 miles) of Yucca Mountain] are also important contributors to ground motions. The uncertainties in the magnitude and location of the earthquakes are incorporated into these analyses. DOE regards this annual frequency as appropriate and conservative because it reflects the annual probabilities of design ground motions for nuclear powerplants in the western U.S. In addition, surface facilities at Yucca Mountain pose less risk than nuclear powerplants. Table 4-36 of the EIS presents earthquake-accident scenarios that use an earthquake frequency of once in 50,000 years. This is roughly equivalent to an earthquake of 7 magnitude on the Richter scale within 5 kilometers of Yucca Mountain, with a mean peak ground acceleration of 1.1 *g*, where *g* is acceleration due to gravity (980 centimeters per second squared) at the waste-emplacement depth. These are very conservative calculations that give an indication of the maximum impact of such an event. Subsurface facilities would be built in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have less affect on subsurface facilities than on surface facilities. Inspection of existing tunnels in the Yucca Mountain area has revealed little evidence of disturbance after earthquakes. Vibratory ground motion from earthquakes that might occur along faults in the Yucca Mountain region will propagate through the rock at wavelengths that are very long compared to the dimensions of emplacement drifts, boreholes, and fissures. For instance, a 1-Hertz seismic shear wave propagating with a velocity of 610 meters (2,000 feet) per second (an approximate value for the near-surface rocks) has a wavelength of 610 meters; a 10-Hertz wave has a wavelength of 61 meters (200 feet). Even wavelengths as long as 61 meters are much larger than the diameter of the proposed emplacement drifts and any previously drilled boreholes. This implies that significant strains associated with the passage of earthquake-excited seismic waves are not set up across the drifts or boreholes. An excavation tends to move as a unit and therefore the impact is minimal.

7.5.3.3 (724)
Comment - EIS000210 / 0002
It is my hypothesis that as greenhouse gasses continue to be added to the atmosphere over the next several hundred years, global climate change will be exacerbated by ever increasing severe weather events with very large water mass shifts geographically. So what? You might say ... What has that got to do with Yucca Mountain? Well, as the continental plates experience large mass load shifting, does it not stand to reason that there will be an increased incidence of seismic activity? But nuclear power does not produce any CO2, you might add; but it does produce Pu238 which may be released to the biosphere during a seismic cataclysm.

Response
DOE used several geophysical methods, including seismic reflection, gravity, and magnetic surveys, to characterize the subsurface geologic structure of Yucca Mountain. A single magnetotelluric line and several vertical seismic profiles provided supplementary information.

DOE conducted a 32-kilometer (20-mile)-long seismic reflection survey across Bare Mountain, Crater Flat, Yucca Mountain, Midway Valley, and Fortymile Wash. Where this regional profile crosses the repository site, the reflection data show a series of west-dipping normal faults that displace volcanic rocks and the Tertiary/pre-Tertiary contact at depth. DOE collected gravity data along geophysical survey lines and used them to interpret general regional structure and to aid in interpretation of the shallow structure at Yucca Mountain, such as the location and displacement of faults. The Department conducted ground magnetic surveys to infer fault locations and displacements. Because buried faults and geologic heterogeneities at Yucca Mountain are a concern for the long-term performance of the repository, DOE used magnetotelluric methods to detect and characterize these features.

DOE combined information from these geophysical studies with results from other field studies, included extensive surface mapping of geologic features and mapping in the Exploratory Studies Facility. In addition, boreholes provided information on the vertical and lateral distribution of hydrogeologic units, hydrologic properties of the rocks, thermal and other geophysical conditions and properties, chemistry of the contained fluids, pneumatic pressure, and water content and potential. Additional data for some of these parameters came from the excavations for the Exploratory Studies Facility and from boreholes drilled from the drifts or alcoves in the Exploratory Studies Facility.

Using this combined data set, DOE derived detailed geologic and hydrologic models to describe the spatial models of rock layers, faults, rock properties, and mineral distributions in the subsurface and to simulate three-dimensional fluid flow and support site-performance models of Yucca Mountain. For a more complete discussion of site-scale geophysical studies, see Section 4.6.5 of the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000).

Internal processes in the earth, rather than climate, drive the tectonic plates. The different land and ocean configurations resulting from continental drift, along with the location and height of mountain ranges, that affect the climate occur over thousands of millennia. Conversely, shorter-term climatic variations caused by such things as the Earth's orbital cycle and solar output cycles can occur over decades to thousands of years. These shorter-term changes have the potential to affect the long-term performance of a repository. A number of phenomena affect the energy budget of the atmosphere on short time scales, ranging from decades to several centuries. These events include perturbations such as solar variability, volcanism, carbon dioxide variations, and the El Niño Southern Oscillation. Human-caused increases in carbon dioxide have generated much scientific and public concern, because higher concentrations of atmospheric carbon dioxide act as a trap for outbound long-wave radiation, thus warming the Earth.

The consequences of a warmer Earth will almost certainly result in greater amounts of water vapor entering the atmosphere, which should increase precipitation in some areas. However, it is not known if climate changes affect carbon dioxide levels or vice versa. Section 6.2 of the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) documents the timing, magnitude, and character of past climate changes in the Yucca Mountain area and establishes the rationale for projecting such changes into the future. Based on this information, a model of climate change has been developed in which the modern-day climate at Yucca Mountain would persist for another 400 to 600 years, followed by a warmer and much wetter monsoon climate for 900 to 1,400 years, followed by a cooler and wetter glacial-transition climate for 8,000 to 8,700 years.

The commenter refers to the structural evolution of the site and surrounding area and to tectonic processes operating in the vicinity of Yucca Mountain that have the potential to cause events that could affect the performance of a repository. The commenter is particularly concerned about the possibility of increased seismicity caused by plate tectonics. As discussed in Section 3.1.3.3 of the EIS, DOE has been monitoring earthquake activity in the Nevada Test Site region since 1978. The Yucca Mountain Program investigates faults and earthquakes to assess seismic hazards at the site.

DOE recognizes that the effect of earthquakes on a repository at Yucca Mountain is a major concern, and has conducted an extensive seismic hazard analysis. The analysis, completed in 1998, involved 25 experts from industry, academia, and government. The expert assessments indicate that the hazards of geologic fault displacement are low. Results of long-term performance assessments of the subsurface repository indicated no significant effects on waste isolation from earthquakes. Using this seismic hazard information, DOE would design surface facilities at the repository to withstand the effects of earthquakes that could occur during the lifetime of these facilities. The seismic design requirements for the repository specify that structures, systems, and components important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain. Section 3.1.3.3 of the EIS contains more information.

Subsurface facilities would be built in solid rock. Because vibratory ground motion decreases with depth, earthquakes would affect subsurface facilities less than surface facilities. Inspection of existing tunnels in the Yucca Mountain area has revealed little evidence of disturbance after earthquakes. Sections 3.1.3.3 and 5.7.3 of the EIS contain more information.

After closure of the proposed repository, there would be a limited potential for releases to the atmosphere because the waste is isolated far below the ground surface. The potential for gas transport of carbon-14 was analyzed because the repository host rocks are porous. Modeling shows negligible human health impacts due to releases of gas-phase carbon-14. See Section 5.5 of the EIS for additional information on atmospheric radiological consequences.

7.5.3.3 (856)
Comment - EIS000173 / 0015
Geologic factors, in addition to rapid groundwater flow in the unsaturated zone, increase the risk and uncertainty about loss of waste containment and isolation at the Yucca Mountain site. Seismic risk is said by project officials to be "acceptably low," but it is acknowledged that the potential exists during the hazardous lifetime of the waste, for the repository to be impacted by an earthquake nearby in the magnitude range of 7.0 to 7.5.

The potential for large nearby earthquakes exists during the operational life of the surface facility of the repository. An unexpected magnitude 5.6 earthquake occurred at Little Skull Mountain, adjacent to the study site in June 1992. This quake was associated with a much larger event in Southern California.

Operation of a nuclear waste repository at Yucca Mountain will require three irradiated fuel pools to facilitate waste transfer operations. The faulting and earthquake history of the area is such that a nuclear power reactor with its irradiated fuel pools could not be licensed there. Therefore, on what basis does the Department intend to locate multiple irradiated fuel pools at the Yucca Mountain site? This unresolved issue is of critical importance.

Response
An extensive seismic hazard analysis was completed in 1998 involving 25 experts from industry, academia, and government. The expert assessments indicate that the fault-displacement hazard is generally low. Results of long-term performance assessments of the subsurface repository indicated no significant effects on waste isolation from earthquakes. The surface and underground facilities at Yucca Mountain are being designed to withstand ground motion from earthquakes. The analysis determined that an annual frequency of 1×10^{-4}, or the 10,000-year earthquake, is an appropriate level for preclosure design of structures that are important to safety. At Yucca Mountain, these structures would be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4}. For the 10,000-year earthquake, the design motions are dominated by the contribution of normal-fault type earthquakes of magnitude 6.3 with an epicenter within 5 kilometers (3 miles) of Yucca Mountain that respond to higher structural frequencies. At lower frequencies, contributions from strike-slip type earthquakes of magnitude 7.5 or greater events in Death Valley [within 50 km (31 miles) of Yucca Mountain] are also important contributors to ground motions. The uncertainties in the magnitude and location of the earthquakes are incorporated into these analyses. DOE regards this annual frequency as appropriate and conservative because it reflects the annual probabilities of design ground motions for nuclear powerplants in the western U.S. In addition, surface facilities at Yucca Mountain pose less risk than nuclear powerplants. Tables 4-36 and 4-37 of the EIS present earthquake-accident scenarios that use an earthquake frequency of once in 50,000 years. This is roughly equivalent to a 7 magnitude on the Richter scale within 5 kilometers (3 miles) of Yucca Mountain, with a mean peak ground acceleration of 1.1*g* at the waste-emplacement depth. These are very conservative calculations that give an indication of the maximum impact of such an event.

7.5.3.3 (972)
Comment - EIS000230 / 0001
The recent 7.1 magnitude Hector Mine earthquake of 10-16-99 occurred on the Lavic Lake fault, which was previously mapped by Thomas Dibblee Jr. of the USGS approximately 30 years ago. At the time the fault was not named.

Previous evaluations of the Lavic Lake fault by the California Division of mines and Geology showed the fault had not produced a large earthquake within the last 10,000 years. The Hector mine quake created a rupture of 40 km with a maximum offset of 3.8 to 4.7 meters.

The Landers earthquake, with a magnitude of 7.4, and the Joshua Tree quake occurred 7 years previous to the Hector Mine quake. These three faults are all included in the same fault zone area, and the California Division of mines stated in their report this could not occur, but it did.

The current USGS view is that these faults remain inactive for thousands of years and then become active for several hundred years before returning to quiescence. This information was obtained from various USGS websites.

Could this same pattern of activity occur in the Yucca Mountain area?

The Skull Valley earthquake of June 1992, with a magnitude 5.6 was triggered by the Lander quake. This scenario will occur again.

If the Lavic Lake and Landers faults are creating more stress on the Yucca area faults further and immediate study is needed to determine the new risks and hazards. Just based on Wernicke's work the current DEIS is not sufficient and requires further study.

Response
Since the advent of worldwide seismograph networks, seismologists have observed that many large fault systems around the world remain inactive for long periods and then become active for relatively brief periods before returning to relative quiescence. Periods between major faulting episodes vary and are generally related to rates of large-scale plate motions. This episodic pattern of fault displacements is probably true for the Yucca Mountain region as well, where trenching investigations indicate that many of the faults in the region have relatively long recurrence intervals (time periods between successive displacements). Monitoring of these faults indicate that the seismicity associated with displacement is of low intensity and the recurrence rate is approximately 20 times less than a typical area of comparable size in the southern Great Basin.

There is fairly reliable evidence that the Landers earthquake (magnitude 7.3) triggered the June 1992 Little Skull Mountain earthquake (magnitude 5.6). The evidence suggests that the passage of large surface waves over the pending rupture zone at Little Skull Mountain triggered foreshocks that were followed about 20 hours later by the magnitude 5.6 mainshock. In other words, the surface waves from the Landers earthquake provided the incremental stress required to initiate rupture and, if the Landers earthquake had not occurred, the Little Skull Mountain fault zone would have ruptured at another time.

7.5.3.3 (973)
Comment - EIS000230 / 0002
According to Caltech, since the Hector Mine quake faults have been "talking" to one another. By this they mean that since the Hector Mine quake stress has increased on some faults and decreased on others and at this point it is impossible to tell where the stress has increased. Has it increased in the Yucca Mountain area?

Since the western Mojave desert faults are now "talking" to other faults the public needs to know the consequences. Further study is needed in this area immediately.

Response
The magnitude 7.1 Hector Mine earthquake of October 1999 occurred about 240 kilometers (150 miles) from Yucca Mountain. While it is unlikely that major displacements or changes in the stress field at Yucca Mountain were associated with this earthquake, it would require a resurvey of the 14-station geodetic network that the U.S. Geological Survey installed in 1983 to be able to make a quantitative statement. The geodetic network would not be sensitive to any rigid-body motion of the network as a whole, but would have to experience relative station-to-station displacements (strains) above ambient noise levels.

Ground accelerations recorded at a network of three-component strong-motion instruments operating in the Yucca Mountain area during the Hector Mine earthquake did not exceed 0.014*g*, where *g* is acceleration due to gravity (980 centimeters per second squared). These levels of acceleration are more than 10 times smaller than the anticipated earthquake-design levels for surface and underground facilities at the repository.

7.5.3.3 (977)
Comment - EIS000230 / 0006
One must also consider what a magnitude 7 earthquake would do to the Yucca Mountain area. It would certainly disrupt road and rail lines as well as power and communications.

Response
In 1998, 25 experts from industry, academia, and government completed an extensive seismic-hazard analysis of the Yucca Mountain area. These assessments indicate that the fault-displacement hazard at Yucca Mountain is generally low. Results of long-term performance assessments of the subsurface repository indicated no significant effects on waste isolation from earthquakes. Using the seismic hazard information, the surface and underground

facilities at Yucca Mountain are being designed to withstand ground motion from earthquakes. The analysis determined that an annual frequency of 1×10^{-4}, or the 10,000-year earthquake, is an appropriate level for preclosure design of structures that are important to safety. At Yucca Mountain, these structures would be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4}. For the 10,000-year earthquake, the design motions are dominated by the contribution of a normal-fault earthquakes of magnitude 6.3 with an epicenter within 5 kilometers (3 miles) of Yucca Mountain that respond to higher structural frequencies. At lower frequencies, contributions from strike-slip type earthquakes of magnitude 7.5 or greater events in Death Valley [within 50 kilometers (31 miles) of Yucca Mountain] are also important contributors to ground motions. The uncertainties in the magnitude and location of the earthquakes are incorporated into these analyses. DOE regards this annual frequency as appropriate and conservative because it reflects the annual probabilities of design ground motions for nuclear powerplants in the western U.S. In addition, surface facilities at Yucca Mountain pose less risk than nuclear powerplants.

Earthquakes can disrupt power transmission, communications, roads, and rail lines. Tables 4-36 and 4-37 of the EIS present earthquake-accident scenarios that use an earthquake frequency of once in 50,000 years. This is roughly equivalent to a 7 magnitude on the Richter scale within 5 kilometers (3 miles) of Yucca Mountain, with a mean peak ground acceleration of 1.1*g*, where *g* is acceleration due to gravity (980 centimeters per second squared) at the waste-emplacement depth. These are very conservative calculations that give an indication of the maximum impact of such an event. Appendix H contains additional analysis of accidents due to seismic activity.

7.5.3.3 (1045)
Comment - EIS000315 / 0002
Speaking of shake and bake or the ground movement when nuclear waste is present, the earthquake issue continues to astound us Nevadans, and I was surprised to hear that there's no definitive answer that was given today about what standard the repository is going to be designed for, whether it's a 6.5 or whether it's other standards; those still haven't been made yet. And you know why? It's because of the same thing, you know, that what we've heard earlier. Just like the groundwater travel time, once they find that -- Standards are set, but once the mountain can't meet those standards, they go back and change the standards. Well, at least with earthquakes, you know, now you're not going to set them yet; first, you're going to see what the math would be, and then you're going to say, "Oh, our repository can withstand that." You know, also just last week, only a short distance from Yucca Mountain in the Mojave Desert, we had a 7.0 earthquake. High-rise buildings in Las Vegas were evacuated. A train was forced off of its tracks.

Response
DOE has not proposed to "change the standards" in 10 CFR Part 960 by which the suitability of the Yucca Mountain is evaluated. Rather, the purpose of the new Yucca Mountain-specific guidelines (10 CFR Part 963) is to implement the NWPA, consistent with the current regulatory framework and technical basis for assessing the ability (or performance) of a geologic repository to isolate spent nuclear fuel and high-level radioactive waste from the environment.

The Nuclear Waste Policy Act of 1982 [Section 112(a)] directed the Secretary of Energy (and by extension, DOE) to issue general guidelines for the recommendation of sites for characterization, in consultation with certain Federal agencies and interested Governors, and with the concurrence of the NRC. These guidelines (issued in 1984 at 10 CFR Part 960) were to include factors related to the comparative advantages among candidate sites located in various geologic media, and other considerations such as the proximity to storage locations of spent nuclear fuel and high-level radioactive waste, and population density and distribution.

In 1987, amendments to the Nuclear Waste Policy Act specified Yucca Mountain as the only site DOE was to characterize. For this reason, DOE proposed in 1996 to clarify and focus its 10 CFR Part 960 guidelines to apply only to the Yucca Mountain site (which would be codified at 10 CFR Part 963), but never issued these guidelines as final. In 1999, DOE proposed further revisions to the draft Part 963 guidelines for three primary reasons:

1. To address comments that criticized the omission of essential details of the criteria and methodology for evaluating the suitability of the Yucca Mountain site.

2. To update the criteria and methodology for assessing site suitability based on the most current technical and scientific understanding of the performance of a potential repository, as reflected in the DOE report, *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998).

To be consistent with the then-proposed site-specific licensing criteria for the Yucca Mountain site issued by the Nuclear Regulatory Commission (the Commission has since finalized these criteria at 10 CFR Part 63), and the then-proposed site-specific radiation protection standards issued by the Environmental Protection Agency (the Agency has since finalized these standards at 40 CFR Part 197). DOE issued final 10 CFR Part 963 in 2001.

Earthquakes can disrupt power transmission, communications, roads, and rail lines. Table 4-35 of the EIS presents earthquake-accident scenarios that use an earthquake frequency of once in 50,000 years. This is roughly equivalent to a 7 magnitude on the Richter scale within 5 kilometers (3 miles) of Yucca Mountain, with a mean peak ground acceleration of 1.1*g*, where *g* is acceleration due to gravity (980 centimeters per second squared) at the waste-emplacement depth. These are very conservative calculations that give an indication of the maximum impact of such an event. Appendix H contains additional analysis of accidents due to seismic activity.

7.5.3.3 (1070)
Comment - EIS000287 / 0003
Furthermore, is it genuinely a better move to place waste in an area which is rocked with considerable seismic activity?

Response
In 1987, Congress selected Yucca Mountain as a potential location for a monitored geologic repository, and directed DOE to determine whether the site is suitable. Some of the reasons Congress selected Yucca Mountain for study include a deep water table, favorable geology, a desert environment, and the fact that the Nevada Test Site is already a controlled area. Based on the results of analyses reported in Chapter 5 of the Draft EIS, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with the Environmental Radiation Protection Standards for Yucca Mountain, Nevada, 40 CFR Part 197. DOE also believes that the impacts of leaving the waste at 77 sites throughout the country (the No-Action Alternative) outweigh the impacts of permanent disposal at Yucca Mountain. See Section 2.4 of the EIS for more information.

7.5.3.3 (1375)
Comment - EIS000432 / 0003
The DOE also wants the construction and emplacement of waste packages in a mass of volcanic rock. Again the DOE states that it is “unlikely” that any additional silicic activity would occur. However in 1992, there was an earthquake at Little Skull Mountain measuring 5.6 on the Richter scale. Little Skull Mountain is located 12 miles southeast of the proposed site. Of course the DOE estimates that after closure there is a 1 in 7,000 chance of volcanic disruption for the first 10,000 years. But how long does it take before this spent nuclear fuel and radioactive waste is no longer hazardous or dangerous to humans and the environment?

Response
As discussed in Section 3.1.3 of the EIS, Yucca Mountain consists of lithified volcanic ash that fell and flowed onto the site from eruptions of calderas to the north of the site (see Figure 3-5 and Table 3-7). These explosive volcanic eruptions occurred during development of the Southwestern Nevada volcanic field. Basaltic volcanism that began later marked the end of the period of explosive volcanic eruptions. These basaltic eruptions originated deep in the upper mantle and flowed onto Crater Flat. DOE’s estimate of a 1-in-7,000 chance of volcanic disruption of the repository during the first 10,000 years is based on detailed investigations of the basalts. This estimate was recalculated in Section 3.1.3.1 of the Final EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000).

Section 3.1.3.3 of the EIS describes the Little Skull Mountain earthquake, which occurred in an area of persistent recent seismicity that has been monitored by instruments in the Southern Great Basin Seismic Network. This might be a zone of stress concentration, accommodating strain from fault systems throughout the south central Nevada Test Site area. This earthquake appears related to the Rock Valley fault system and not to any volcanic or magmatic activity.

Section 5 of the EIS describes the components and summarizes the results of DOE's assessments of long-term repository system performance over the 10,000-year period of regulatory interest and for the longer 1-million-year period for potential volcanic events. The performance assessments considered the inventory of long-lived radionuclides and their potential pathways to the accessible environment. The analysis of long-term repository performance shows that the combination of natural and engineered barriers at the site would keep doses resulting from any releases of radionuclides well below the regulatory limits established by the Environmental Protection Agency in 40 CFR Part 197. While the potential consequence (dose) related to a volcanic event can never be completely eliminated, it would be greatly diminished after 1,000 years. Section 5.7.2 of the EIS presents the annual risk over a 10,000-year period.

7.5.3.3 (1475)
Comment - EIS000485 / 0003
The reactors where the waste is now stored are licensed by the NRC [Nuclear Regulatory Commission] and are on solid, stable ground with negligible earthquake activity. By contrast, the area where they propose to ship the waste is among the most seismically active in the country and would not meet the same NRC licensing standards for reactors. Since site characterization studies for the Yucca Mountain dump began, there have been dozens of earthquakes, including a magnitude 5.2 quake in 1992 which caused over a million dollars in damage to government buildings at the Yucca Mountain site. There have been 621 seismic events of a 2.5 magnitude or greater in the last 20 years.

Response
DOE recognizes that the effect of earthquakes on the proposed repository at Yucca Mountain is a major concern, and has conducted extensive analyses. The EIS analyzes the probability of earthquake occurrence and the environmental consequences. To support this analysis, DOE and the U.S. Geological Survey performed a comprehensive evaluation of the seismic hazards in the Yucca Mountain region using standard practices of mapping, trenching, age-dating, and monitoring of contemporary seismicity. Then DOE-sponsored groups of experts from inside and outside the Project used this site data to assess the seismic hazard potential of major seismic sources in the region. Another group of experts used numerical modeling methods and data from recent earthquakes to estimate ground motion attenuation relationships appropriate for Yucca Mountain.

Using the seismic hazard information, DOE would design repository surface facilities to withstand the effects of earthquakes that could occur during the lifetime of these facilities. The seismic design requirements for the repository specify that structures, systems, and components important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

DOE has determined that an annual frequency of 10^{-4}, or the 10,000-year earthquake, is an appropriate level for preclosure design of structures important to safety, so it would design these structures to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4}. DOE regards this annual frequency as appropriate and conservative because it reflects the annual probabilities of design ground motions for nuclear powerplants in the western United States. (Originally, utilities developed design bases for nuclear powerplants deterministically, but recently have determined the annual probability of design events. The range is 10^{-3} to 10^{-4}.) The annual frequency of 10^{-4} is more conservative than that for the powerplants licensed by the Nuclear Regulatory Commission. Also, surface facilities at Yucca Mountain would be inherently less dangerous facilities.

DOE would build subsurface facilities in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have less effect on subsurface facilities than surface facilities. Inspections of tunnels in the Yucca Mountain area have revealed little evidence of disturbance following earthquakes. DOE would design the subsurface facilities and waste package to withstand the effects of earthquakes for the long-term performance of the repository.

Recent earthquakes at Scottys Junction, Nevada [August 1, 1999, magnitude 5.7, about 80 kilometers (50 miles) from Yucca Mountain] and at Hector Mine, California [October 16, 1999, magnitude 7.1, about 250 kilometers (155 miles) from Yucca Mountain] had no effects at Yucca Mountain. These events produced ground motions recorded at Yucca Mountain that were more than 20 times smaller than seismic design motions for the proposed surface facilities, as would be expected given their distance from the site. The Scottys Junction earthquake had a similar magnitude, depth, and normal focal plane solution as the Little Skull earthquake in 1992, which was the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain (a Richter magnitude 5.6). The Little Skull Mountain earthquake, with an epicenter 20 kilometers (12 miles) to the southeast, caused no damage at Yucca Mountain. It did damage the Yucca Mountain Field Operations Center in Jackass Flat, about 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), but this facility was not built to the seismic-design specifications planned for surface facilities at Yucca Mountain. This earthquake caused less than $100,000 damage, although DOE spent additional funds on structural modifications to bring the building into compliance with existing codes. The Department would design Yucca Mountain facilities for a similar earthquake centered near the site. Section 3.1.3.3 of the EIS contains more information.

7.5.3.3 (1484)
Comment - EIS001521 / 0023
Page 3-29, 3.1.3.3 MODERN SEISMIC ACTIVITY, first paragraph--References are needed for all the assertions made in this paragraph. For instance, it is not common knowledge that regional earthquake epicenters do not correlate with Quaternary faults in the Yucca Mountain area (a figure would also be nice).

Response
Section 3.1.3 of the EIS is based on information contained in the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000). DOE cited this broad-based reference in the EIS because it has collected an enormous amount of baseline environmental data that are contained in many separate reports. To cite a separate report in the EIS each time a reference to such a report was made would have been very cumbersome for the reader. Instead, the Department cited the *Yucca Mountain Site Description*, which references these other, detailed reports.

With respect to the example cited by the comment ("...regional earthquake epicenters do not correlate with Quaternary faults in the Yucca Mountain area..."), this statement is from Section 12.3.5 of the Site Description. This reference supports the assertion with a figure showing epicenters and focal mechanisms of earthquakes and known and suspected Quaternary faults near Yucca Mountain. DOE agrees that such a figure would be of interest to readers with specific interest or expertise in seismic activity, but DOE believes that this level of detail is not needed for the EIS.

7.5.3.3 (1520)
Comment - EIS000474 / 0001
People who do not understand geology, and who believe one state is like another, as long as it is land, are likely to seize upon Circular 1184 as indication that Yucca Mountain would be feasible for radioactive waste burial. But the one thing DOE, nor any other organization, could not possibly prepare against is a catastrophic event. Such cannot be predicted or prepared for, and when the time came it would be too late. This is a catastrophic event country. This is the wrong kind of an environment for such burial. The likelihood of catastrophic events is too great for such a major risk. I believe the Survey needs to point out the risks to the people of this country. And the million of dollars already spent at Yucca Mountain has largely been a waste of funds. That site is one of the worst decisions ever made by Congress, for it does not consider geology.

Response
DOE prepared this EIS under the requirements of the Nuclear Waste Policy Act and consistent with the National Environmental Policy Act, and the regulations of the Environmental Protection Agency and the Nuclear Regulatory Commission related to the proposed repository. Geologic stability is one of many criteria that DOE applied in consideration of the Yucca Mountain site.

The EIS analyzes impacts that could arise from catastrophic natural events such as earthquakes and volcanic activity. While DOE cannot predict such events exactly, it can deal with them statistically and incorporate them in the risk analysis. Chapter 5 of the EIS contains an assessment of the probability and effect of such events on long-term radionuclide release and the resultant impacts. The consideration of the combined likelihood and consequences of such events indicate the potential risk.

7.5.3.3 (1832)
Comment - EIS000206 / 0011
Question that is not answered by DOE: Seismic activity -- a particularly important issue in relation to interim storage -- continues to be very active. Yucca Mountain, and the NTS, lie within the second most active seismic area in the continental United States. Well over 600 earthquakes registering over 3.0 on the Richter scale have been recorded in the area in the past twenty years.

Response
DOE does not plan to construct or use interim storage facilities at the proposed repository at Yucca Mountain. The Department would design surface facilities at the repository to withstand the effects of earthquakes that could occur during the lifetime of these facilities. The seismic design requirements for the repository specify that structures, systems, and components that are important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain. Section 3.1.3.3 of the EIS contains more information.

In addition to these seismic design requirements, DOE evaluated sixteen accident scenarios for the repository, including the potential for seismic events beyond the design basis. Of these scenarios, the maximum reasonably foreseeable accident was a seismic event, beyond the design basis, with an annual frequency of occurrence of 2×10^{-5} (once in 50,000 years) that results in the collapse of the Waste Handling Building and damage to 375 fuel assemblies. Details of the accident analysis are presented in Section 4.1.8 of the EIS.

7.5.3.3 (2009)
Comment - EIS000559 / 0002
If you put it in, it will affect the ground water, which will affect the whole state, even nearby states. If we have earthquakes, they will go into the water.

If we have an earthquake as well, it can also affect it into the air. And that will affect Idaho, it will affect Oregon, it will affect California, it will affect us.

Response
As discussed in Section 3.1.3.3 of the EIS, DOE has been monitoring earthquakes in the Nevada Test Site region since 1978. The site characterization program studies faults and earthquakes to assess seismic hazards at the site. DOE used panels of experts with access to all available information to complete a probabilistic seismic-hazard assessment. The results of this study indicated that the probability of reactivating faults at the site is very small. Additional fault movements or displacements from postemplacement seismic activity probably would occur on existing fault planes. Using the seismic-hazard information, DOE would design repository facilities to withstand the effects of earthquakes that could occur during the lifetime of the facilities. The seismic-design requirements for the repository specify that structures, systems, and components important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years).

There is no direct relationship between earthquake occurrence and potential radionuclide releases from the waste package. The current design calls for waste packages to be placed on pallets and not in boreholes drilled into the repository walls or floors. If an earthquake occurred at or near the site, fault displacements would not result in waste package failure because the emplacement areas would be away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release. Calculations show that there would be almost no effect on repository performance from rockfall by vibratory ground motion.

DOE based its hydrology models, derived from extensive studies conducted at Yucca Mountain, on a fault-fracture dominant flow system. The hypothetical addition of new faults would have very minor or no effect on the current fault and fracture flow pathways. Such potential faults and fractures, therefore, would be unlikely to alter repository performance.

As discussed in Section 3.1.4 of the EIS, Yucca Mountain is in a closed hydrologic basin. Surface water and groundwater can leave the basin only by evapotranspiration. The regional slope of the water table (potentiometric surface) indicates that groundwater flows southward toward Amargosa Valley. The Central Death Valley subregion is comprised of three groundwater basins that are subdivided into smaller sections. Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin. In this basin only a small portion of total basin recharge actually infiltrates through Yucca Mountain. The small fraction of water that does infiltrate and becomes groundwater recharge and then flows towards Fortymile Wash and discharges with the rest of the groundwater in the Fortymile Canyon section of the groundwater basin. Flow then continues south toward Amargosa Valley in the Amargosa River section as shown in Figure 3-13 of the EIS. The natural discharge of groundwater from beneath Yucca Mountain is probably farther south at Franklin Lake Playa more than 60 kilometers (37 miles) away and therefore would not affect groundwater in the entire state. Modeling of the long-term performance of the repository shows that the combination of natural and engineered barriers at the site would keep such a release small enough to pose no significant impact on the health and safety of people or the environment. See Section 3.1.4.2.2 and 5.4 of the EIS for additional information.

After closure of a proposed repository, there would be a limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. The potential for gas transport of carbon-14 was analyzed because the repository host rocks are porous. Modeling analyses show negligible human-health impacts due to releases of gas-phase carbon-14. See Section 5.5 of the EIS for additional information on atmospheric radiological consequences. DOE does not expect any health effects due to atmospheric releases in Oregon, Idaho, and California. Moreover, there is no indication that the vibratory ground motion and fault-displacement hazard would affect these analyses.

7.5.3.3 (2031)
Comment - EIS000564 / 0004
And that also brings us to the earthquake question. Last month only a short distance from Yucca Mountain in the Mojave Desert, a 7.0 earthquake forced a train to jump from its tracks and some high rise buildings were evacuated in Las Vegas, even though the earthquake occurred about 150 miles away.

Now the earthquake specifications for Yucca Mountain are still being talked about. And that brings us to the point of standards.

Response
As mentioned by the commenter, on October 16, 1999, the magnitude 7.1 Hector Mine earthquake occurred in the Mojave Desert approximately 240 kilometers (150 miles) from Yucca Mountain. Peak ground accelerations recorded in the Yucca Mountain area during that earthquake did not exceed 0.014*g*, where *g* is acceleration due to gravity (980 centimeters per second squared). These levels of acceleration are more than 10 times smaller than anticipated design levels for the surface and underground facilities at the repository, which would, therefore, withstand the effects of ground motion from earthquakes of this size at that distance. The design basis earthquake for ground motions in the frequency range 1 to 2 hertz corresponds to earthquakes of magnitude 7 or larger at a distance of about 48 kilometers (30 miles).

7.5.3.3 (2199)
Comment - EIS000608 / 0001
Nevada per area square miles is probably the most seismic state in the nation. This is an extension area here that as the earth cools off, there are going to be more problems form or you have more earthquakes happening.

This is ridiculous that they want to bury nuclear waste here. It really is. They should put it out in the plains of Nebraska or something where it's more stable.

Response
The State of Nevada ranks third, behind Alaska and California, in terms of seismic activity. Its reputation as a highly active state comes primarily from the occurrence of major historic earthquakes (a Richter-scale magnitude of 7 or higher) along the Central Nevada Seismic Belt in western Nevada (DIRS 151945-CRWMS M&O 2000). This seismic belt, which is characterized by geologically young faults, appears on seismicity maps to be an extension into Nevada of fault systems in southwestern California (such as the Death Valley-Furnace Creek fault system). The Central Nevada Seismic Belt splits near the California-Nevada border. One belt of seismic activity enters the Reno-Carson City area, and the other belt heads approximately due north from the border and crosses the western tip of Nye County on its way to central Nevada. While earthquakes do not occur at regular intervals, the average

frequency of magnitude 6 and greater earthquakes in western Nevada is about one every 10 years, while earthquakes of magnitude 7 and greater average about one every 27 years.

In contrast, the largest recorded earthquakes within 100 kilometers (60 miles) of Yucca Mountain were the June 29, 1992, magnitude 5.6 Little Skull Mountain earthquake, and the August 1, 1999, magnitude 5.7 Scottys Junction earthquake. DOE recognizes the potential seismic hazard at Yucca Mountain and has conducted extensive geologic and geophysical investigations in the region over the past 20 years. More than 50 trenches have been excavated along mapped faults in the Yucca Mountain area. The data obtained from trenching indicate that the faults have not ruptured the surface for thousands of years. In 1998, the Project ended a multiyear study of the seismic hazard at Yucca Mountain. This study involved 25 earth scientists from academia, industry, and government who reviewed project data and information from many organizations and arrived at an estimate of the hazard associated with ground motion and fault displacement at Yucca Mountain. This estimate, in conjunction with targeted geotechnical investigations (to define the properties of the rocks close to the surface), will form the seismic-design bases of surface and underground facilities at Yucca Mountain that are important to safety.

7.5.3.3 (2256)
Comment - EIS000362 / 0001
I want to relate a little story of living over here and the kind of geology we have. I had the pleasure a year or so ago of having a couple of Ph.D. geologists stay with me and my wife at our home, which overlooks the Owens Valley. Over a period of a couple days, they spent most of their time out on our terrace discussing what they saw, discussing earthquake faulting, discussing -- who knows what they were discussing. It wasn't real clear to us what they were discussing. But after a couple days of this, two white-haired Ph.D. geology professors, both worked for the oil companies at one point in their lives, my wife asked one of them, the older one, she says, "So, Claude, what is it you see when you look out here at what's around this area in the Owens Valley?" He says, "I see a real mess." And it seems to me that says a lot about what you can know of geological processes and about what's out here, and what's here between here and Yucca Mountain, and that that should temper the kind of judgments you make about how stable and how reliable the country is for what's being proposed to be done to it.

While you're here, if you haven't done so already, I would urge you to go about one-third of a mile up the road and visit the graveyard of the earthquake for the victims of the 1872 earthquake in Lone Pine, which I don't see in your Draft EIS. It was one of the two or three, or perhaps, the largest earthquake ever in the United States. It would certainly have been very well felt at Yucca Mountain.

And I'm troubled that you've limited your earthquake evaluation to 30 kilometers of the mountain. We know. We feel them all the time, large earthquakes, and we're only 100 miles by air from Yucca Mountain. I would like to see that scale in time and space of your evaluation relative to hydrology and volcanism and earthquakes expanded to an area that certainly could impact the Yucca Mountain site in the not-too-distant future.

Response
The region of interest for assessing seismic hazards at Yucca Mountain is a function of earthquake magnitude and the rate of earthquake occurrence. Because earthquake ground motions lessen with distance, the farther an earthquake occurs from Yucca Mountain, the larger it must be to contribute significantly to the hazard at the site. At a distance of 100 kilometers (62 miles) from Yucca Mountain, earthquakes must reach an estimated magnitude of about 8 on the Richter scale to produce horizontal accelerations of 0.1*g*, where *g* is acceleration due to gravity (980 centimeters per second squared), at the site (DIRS 151945-CRWMS M&O 2000).

Although the focus of the seismic hazard analysis was the area within 100 kilometers (62 miles) of Yucca Mountain, the analysis also considered the historic seismicity between 1868 and 1996 within 300 kilometers (about 185 miles) of Yucca Mountain. This extension of the area of consideration includes many of the major historic earthquakes in California, including the 1872 Owens Valley earthquake, and enables an evaluation of the seismicity of the Yucca Mountain vicinity within a broader regional context. This approach was the basis for the characterization of background earthquakes as part of the probabilistic seismic hazard analyses (DIRS 151945-CRWMS M&O 2000).

7.5.3.3 (2701)

Comment - EIS000956 / 0005

This site should be rejected as unsuitable since it is classified in the highest risk category for earthquakes. Further, it will not retain radioactive gases, such as Carbon-14 and thus cannot meet the original repository standards set by the EPA. IT ALSO SITS ON TOP OF A MAJOR AQUIFER SHARED BY A NEARBY FARMING COMMUNITY, INCLUDING A LARGE DAIRY, SERVING LOS ANGELES MARKETS.

Response

One of the primary objectives of DOE's characterization of the Yucca Mountain area is to identify faults with known or suspected Quaternary activity (during the past 1.6 million years) that could affect the design and performance of the repository. As discussed in Section 3.1.3.3 of the EIS, DOE has monitored earthquakes in the Nevada Test Site region since 1978. The site characterization program studies faults and earthquakes to assess seismic hazards at the site. The identification and documentation of earthquakes occurring before recorded history is possible by studying the geologic record of past events. DOE has constructed the prehistoric earthquake record at Yucca Mountain from the results of paleoseismic and geochronologic studies.

In 1998, 25 experts from industry, academia, and government completed an extensive seismic-hazard analysis of the Yucca Mountain area. These assessments indicate that the fault-displacement hazard at Yucca Mountain is generally low. Results of long-term performance assessments of the subsurface repository indicated no significant effects on waste isolation from earthquakes. Using this seismic hazard information, DOE would design repository facilities that are important to safety to withstand appropriate levels of ground motion and fault displacement. To the extent practical, the location of such facilities would avoid faults that could rupture the surface. The seismic design requirements for the repository specify that structures, systems, and components important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain. Section 3.1.3.3 of the EIS contains more information.

The 1992 Little Skull Mountain magnitude 5.6 earthquake is the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain. This event damaged the Yucca Mountain Field Operations Center in Jackass Flat, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), but this facility was not built to the seismic design specifications planned for the facilities at Yucca Mountain. The waste-emplacement areas would be away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release. Additional fault movements or displacements from postemplacement seismic activity would probably be along existing fault planes.

DOE would build subsurface facilities in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have less effect on subsurface facilities than on surface facilities. Inspections of existing tunnels in the Yucca Mountain area have revealed little evidence of disturbance following earthquakes. The subsurface facilities would be able to withstand the effects of earthquakes for the long-term performance of the repository. Sections 3.1.3.3 and 5.7.3 of the EIS contain more information.

After closure of the proposed repository, there would be a limited potential for releases to the atmosphere because the waste is isolated far below the ground surface. The potential for gas transport of carbon-14 was analyzed because the repository host rocks are porous. Modeling showed negligible human health impacts from releases of gas-phase carbon-14. See Section 5.5 of the EIS for additional information on atmospheric radiological consequences. There is no indication that the vibratory ground motion and fault displacement hazard would alter the results of these analyses.

The EIS did not indicate that there would be no groundwater contamination caused by the repository. Chapter 5 describes the modeling of the long-term performance of the repository which predicts impacts from radioactive and nonradioactive materials released to the environment during the first 10,000 years after closure. The principal means, or pathways, by which these materials would travel to humans and the environment include gradual container failure and leaching of contaminants through the unsaturated zone beneath the repository, then to the groundwater. The Yucca Mountain site characterization effort has gathered sufficient information about the site to make reasonable projections on how and when contaminants would move from the repository.

7.5.3.3 (3523)
Comment - EIS001150 / 0003
Was there any study of the major earthquake of 1992 or 1993, whichever year that took place, at Yucca Flat?

Response
On June 29, 1992, a Richter-magnitude 5.6 earthquake occurred at Little Skull Mountain, about 20 kilometers (12 miles) from Yucca Mountain. This earthquake, the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain, yielded a large amount of data that DOE has used in the assessment of the seismic hazard at Yucca Mountain. Studies based on seismic recordings from the Little Skull Mountain mainshock and aftershocks include the determination of near-surface attenuation of seismic waves, in particular shear waves that are so important in the seismic design of structures, comparison of earthquake source models, focal mechanism of the mainshock and larger aftershocks, and the depth distribution of the earthquake sequence. Other investigations included examination of a 125-meter (410-foot)-deep tunnel within 3 kilometers (2 miles) of the Little Skull Mountain event for possible damage associated with the earthquake. There was no significant damage in the tunnel, which is consistent with observations at underground excavations throughout the world after earthquakes.

7.5.3.3 (3751)
Comment - EIS001029 / 0001
The Department of Energy's process of elaborate technical studies is complex and involves much scientific work but it also involves predictions. In fact, geological estimates or predictions are based on what has happened in the past. But a prediction that earthquakes occur 1,000 to 10,000 years apart is hard to relate to human experience. A 21-year study tells us much about the structure of Yucca Mountain but does not tell us when earthquakes will happen there, exactly where they will happen or how they will change the rocks and fissures that exist. Since 1910, there have been over 600 earthquakes of greater than magnitude-2.5 within a 50-mile radius of Yucca Mountain.[i] How many earthquakes will happen within 50-miles of Yucca Mountain before 1,000 years is over? This Basin area is a dynamic area.[ii]

[i] In the Aug Las Vegas Review-Journal Steve Frishman stated that more than 600 earthquakes of magnitude 2.5 or more, large enough to feel if one is near the epicenter, have been measured within 50 miles of Yucca Mountain since 1910.

From a brochure *Earthquakes in Nevada & how to survive them* by Craig dePolo, Alan Ramelli, & Diane dePolo "Although earthquakes don't occur at regular intervals, the average frequency of earthquakes of magnitude 6 and greater in Nevada has been about one every ten years, while earthquakes of magnitude 7 and greater average once every 27 year."

Response
The frequency and magnitude of seismic disturbances in the vicinity of the Yucca Mountain site have been the focus of a great deal of study by DOE and others. The *Probabilistic Seismic Hazard Analysis for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada* (DIRS 103731-Wong and Stepp 1998) estimated earthquake occurrence frequencies, fault displacement, and vibratory ground motion hazards in the Yucca Mountain vicinity. The safety analyses for construction and operation of the repository as well as the long-term performance models specifically included the effects of seismic events of varying magnitude.

Based on the results of analyses reported in Chapter 5 of the EIS on the long-term performance of the repository, which considered the effects of future seismic and volcanic activity, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with the Environmental Protection Agency's 40 CFR Part 197, *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada*. Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes the impacts from accident scenarios associated with earthquakes during operation of the repository. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. DOE believes that the EIS adequately describes geology, geologic hazards, and the effects of these hazards on the repository.

With regard to the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 explains how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.
2. Consideration of features, events and processes that could affect repository performance over the long-term.
3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.
4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.
5. Parameter distributions that represent the possible change of the system over the long term.
6. Use of conservative assessments that lead to an overestimation of impacts.
7. Performance of sensitivity analyses.
8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

Figures 1 (a plot of Nevada earthquakes between 1852 and 1988) and 2 (active faults in Nevada) from the brochure, *Earthquakes In Nevada and How to Survive Them*, indicate that the highest rate of activity, in terms of number of events and magnitude, occurs in the western portion of Nevada. As noted in a paper by dePolo and other scientists from the University of Nevada, Reno ("Earthquake Occurrence in the Reno-Carson City Urban Corridor," available at www.seismo.unr.edu), 13 earthquakes of magnitude 6 or greater have occurred in the Reno-Carson City region since 1850. In contrast, the largest earthquake within about 40 kilometers (25 miles) of Yucca Mountain recorded to date by a seismic network installed in the area in 1978 was the magnitude 5.6 Little Skull Mountain event on June 29, 1992.

7.5.3.3 (4267)
Comment - EIS001521 / 0024
Page 3-29, 3.1.3.3 MODERN SEISMIC ACTIVITY, fourth paragraph--Did the Probabilistic Seismic Hazard Analysis produce a hazard map? If so, including it as a figure would greatly clarify this discussion. Also, an example of a hazard curve showing ground motion/fault displacement/annual frequency relationships would be helpful.

Response
The probabilistic seismic hazard analysis did not produce a hazard map. Figure H-1 in Appendix H of the EIS is the summary hazard curve for horizontal peak ground acceleration. DOE has added a reference to Figure H-1 for clarification.

7.5.3.3 (4502)
Comment - EIS001455 / 0003
Well, what about the fact that Yucca Mountain is right on two intersecting earthquake faults—the "Ghostdance" fault and the "Sundance" fault? Aw, shucks, there ain't been an earthquake in those parts since 1992, and it was only 5.6 on the Richter scale and it was centered at Little Skull Mountain—that's 12 whole miles away—it "caused no detectable in tunnels at either the Yucca Mountain site or the Nevada Test Site." (P. S-37).

Response
Section 3.1.3.2 of the EIS discusses the north-trending Ghost Dance fault as an intrablock fault that occurs approximately in the middle of the repository block. The Sundance fault intersects the Ghost Dance fault in the northern part of the repository block, but cannot be traced across the fault. Neither fault shows any evidence of Quaternary displacement (last 1.6 million years) (see Table 3-8). Section 3.1.3.3 summarizes the seismic hazard assessment of the site, including information on these faults and other faults in the region.

DOE would design repository facilities that are important to safety to withstand appropriate levels of ground motion and fault displacement. To the extent practicable, the repository design would locate such facilities away from faults that could displace the surface.

The Little Skull Mountain earthquake of 1992, Richter-magnitude 5.6, is the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain. That earthquake, with an epicenter 20 kilometers (12 miles) to the southeast, caused no damage at Yucca Mountain. The event did damage the Yucca Mountain Field Operations Center in Jackass Flat, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), but this facility was not built to the seismic-design specifications that are planned for the facilities at Yucca Mountain.

7.5.3.3 (4841)
Comment - EIS001340 / 0002
The possibility of volcanic like eruptions from the masses of overheated waste is a very possible scenario too.

Response
There is no credible mechanism for the scenario mentioned in this comment. Temperatures would never rise high enough to melt the rock of the drift walls. Drift wall temperatures would approach 200°C (390°F) for the present above-boiling repository design. The major effect from the heat generated by the waste packages would be to drive water away from the drift wall for a period of about 1,500 years. The repository design and operational parameters now described in the EIS include low-temperature options that would keep repository temperatures much lower (that is, below boiling).

7.5.3.3 (4884)
Comment - EIS000337 / 0024
Pg. 5-43 [5-45], Seismic Disturbances, 2nd par: "probably would" and "would have to be larger" have no meaning when one attempts to quantify a problem. What is larger to one may be insignificant to another. We can't at this time quantify an earthquake with any uncertainty but DOE clearly attempts to quantify earthquakes 1,000 years in the future. I am sure the insurance companies and FEMA would like to have their software program.

Response
The commenter refers to wording concerning two aspects of uncertainty about failure of the waste package from rockfalls caused by earthquakes. In the first sentence, "probably would" refers to the uncertainty associated with whether the waste package outer wall would have to be completely corroded following a rockfall impact or whether failure would occur after only partial corrosion or as a result of another mechanism, such as pit corrosion. The second sentence indicates that, based on detailed mapping and measurements, it is highly likely due to waste package design that a rock "would have to be larger" than rocks observed in the Exploratory Studies Facility for a rockfall to cause failure in a recently emplaced, uncorroded waste package.

DOE agrees that we cannot quantify earthquake hazards with uncertainty. The methodology documented in the *Probabilistic Seismic Hazard Analysis* (DIRS 103731-Wong and Stepp 1998) is a state-of-the-practice approach for assessing the vibratory ground motion from earthquakes. The report explicitly addresses uncertainties from lack of data and imperfect understanding of earthquake mechanisms and the resulting ground motion. This approach enables DOE to test uncertainties using sensitivity analysis and allows impartial reviewers and regulators from the Nuclear Regulatory Commission to conduct an independent review of DOE's assessment.

The methodology that DOE used in Wong and Stepp (DIRS 103731-1998) is a site-specific approach based on associating earthquakes with specific geologic structures (faults) or specific regions in the earth's crust. The U.S. Geological Survey uses a non-site-specific probabilistic methodology to assess seismic hazards on a national scale. The results form the basis for the Federal Emergency Management Agency's (FEMA) nationwide approach (FEMA 302). This approach is incorporated in HAZUS, a computer program used by FEMA to assess potential risks (losses) or consequences resulting from earthquakes.

7.5.3.3 (5490)
Comment - EIS001887 / 0158
Page 3-29 to 30; Section 3.1.3.3 - Modern Seismic Activity - Seismic Hazard

Given the large uncertainty in fault lengths shown in Table 3-8, there should be a discussion in the text regarding the uncertainty that this introduces into the estimates of seismic risk.

Response
In 1998, DOE completed an extensive *Probabilistic Seismic Hazard Analysis* (DIRS 103731-Wong and Stepp 1998), involving 25 experts in seismology, paleoseismology, geology, and geophysics. The objectives were to assess available information and provide a probabilistic assessment of the vibratory ground motion and fault-displacement hazards at Yucca Mountain, along with the uncertainties associated with the assessment. Figure H-1 of the EIS shows an example of the results from the Probabilistic Seismic Hazard Analysis. The curves on this figure represent the mean, median, and 85th- and 15th-percentile estimates of the annual probability of exceeding horizontal components of peak ground acceleration. The analysis used a logic-tree approach in which different interpretations form different branches of a logic tree with expert-assigned probabilities to quantify the uncertainties in earthquake source parameters (such as fault length, slip rate, cumulative slip, individual fault-displacement events, and timing of events). The hazard curves in Figure H-1 represent the total uncertainty in parameters and models.

7.5.3.3 (5521)
Comment - EIS001887 / 0179
Page 3-59; Section 3.1.4.2.2 - Groundwater at Yucca Mountain

Define the "active life of the repository."

Response
"Active life" refers to the construction, operation and monitoring, and closure of the repository. DOE has added a parenthetical statement to Section 3.1.4.2.2 of the EIS to clarify this meaning.

7.5.3.3 (5919)
Comment - EIS001619 / 0005
Geologically, the site is clearly, clearly, clearly unsound. In the final EIS I would like to see comments about the recent studies that have proved that the earth's crust near Yucca Mountain is stretching more rapidly than average, and that this could cause unease in the containment facility within the ground.

I would also like to know who can guarantee me that in the next 10,000 years, there's not going to be a gigantic earthquake, which could potentially set this stuff free and do who knows to the planet. Currently the site is on 33 known fault lines, which are active.

Response
As reported in Section 3.1.3.3 of the EIS, Wernicke et al. (DIRS 103485-1998) claims that the crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than the tectonic history of the area would predict. This study speculates that higher strain rates would indicate underestimation of potential volcanic and seismic hazards on the basis of the long-term geologic record.

As discussed in Section 3.1.3 of the EIS, Yucca Mountain is part of a volcanic plateau that formed between 14 million and 11.5 million years ago as a result of explosive silicic volcanic activity originating from a complex of volcanic centers north of the site. About 11 million years ago, this explosive activity began to wane and was replaced by less explosive and much less voluminous basaltic eruptions in the Yucca Mountain region. The most recent basaltic eruption occurred between 70,000 and 90,000 years ago at Lathrop Wells, about 16 kilometers (10 miles) south of the site. A panel of non-DOE experts examined the data, models, and related uncertainties and concluded that the probability of a volcanic dike disrupting the repository during the first 10,000 years after closure is 1 chance in 7,000 (1 chance in 70 million annually). This estimate was recalculated in Section 3.1.3.1 of the Final EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000).

DOE has been monitoring earthquake activity in the Nevada Test Site region since 1978 (see Section 3.1.3.3). It has investigated faults and earthquakes as part of the site characterization program to provide information to assess seismic hazards at the site. Using this information, the Department would design repository surface facilities to withstand the effects of earthquakes that could occur during their lifetimes. The seismic design requirements for the repository specify that structures, systems, and components important to safety would be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (1 in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

In May 1998, U.S. Geological Survey scientists reassessed seismic strain rates (DIRS 118952-Savage, Svarc, and Prescott 1999). The principal strain rates determined during the 1983-1998 survey confirmed previous analyses and were significantly less than those reported by Wernicke et al. (DIRS 103485-1998). The scientists concluded that the residual strain rate in the Yucca Mountain area is not significant at the 95-percent confidence level after removal of effects of the 1992 Little Skull Mountain earthquake and the strain accumulation on faults in Death Valley.

DOE is continuing to fund additional investigations on the regional crustal strain rate in the Yucca Mountain region as specified in a cooperative agreement with the University of Nevada. Dr. Wernicke, the principal investigator of one study, recently estimated in a quarterly report to the DOE that conclusions from this study would be available in 2002. This study involves 30 geodetic monument sites with continuous Global Positioning System satellite measurements, a significant improvement over the study reported in *Science* in 1998. The Department will report conclusions as they become available. If the higher crustal strain rates are confirmed, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

DOE based the hydrology models, which are derived from extensive studies at Yucca Mountain, on a fault-fracture dominant flow system. The hypothetical addition of a few new faults created by future seismic events would have minor or no effects on the current fault and fracture flow pathways. Potential new faults and fractures, therefore, would be unlikely to alter repository performance. However, if there is confirmation of higher crustal strain rates, DOE will reassess the effect on radionuclide transport and total system performance.

DOE agrees that it cannot quantify earthquake hazards without any uncertainty. The methodology documented in the *Probabilistic Seismic Hazard Analysis* (DIRS 103731-Wong and Stepp 1998) is a state-of-the-practice approach for assessing the vibratory ground motion resulting from earthquakes. That report explicitly addresses uncertainties resulting from both lack of data and our imperfect understanding of earthquake mechanisms and the resulting ground motion. This approach enables DOE to test uncertainties using sensitivity analysis and allows impartial reviewers and regulators on the Nuclear Regulatory Commission staff to conduct an independent review of the DOE assessment.

7.5.3.3 (6242)
Comment - EIS001921 / 0008
The selection of a storage site for deadly nuclear waste in an area of seismic activity like Yucca Mountain was unwise. The rapidly expanding population of Las Vegas and vicinity (now well over a million) 90 miles from the repository are surely at risk.

Response

In 1987, Congress selected Yucca Mountain as a potential location for a monitored geologic repository, and directed DOE to determine whether the site is suitable. Some of the reasons that Congress selected Yucca Mountain for study included a deep water table, favorable geology, a desert environment, and the fact that the Nevada Test Site was already a controlled area.

Based on the results of analyses reported in Chapter 5 of the EIS concerning the long-term performance of the repository, which considered the effects of future seismic activity, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with 40 CFR Part 197, *Environmental Radiation Protection Standards for Yucca Mountain, Nevada*). Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes the impacts from accident scenarios associated with earthquakes during operation of the repository. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. With the exception of some factual changes and clarifications in the Final EIS, DOE believes that the information in the Draft EIS on geology, geologic hazards, and the effects of these hazards on the repository, have been adequately described and analyzed.

With regard to the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 of the EIS devotes almost seven pages of text explaining how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

Based on the results of site characterization, and in consideration of this EIS, the Secretary of Energy will make a recommendation to the President about whether Yucca Mountain is a suitable site for a geologic repository.

7.5.3.3 (6863)
Comment - EIS001466 / 0008
I looked around and there was a seismograph measuring the earthquakes at the small field office near the mountain. There was a flying buttress that had been built after the '92 earthquake which was 5.6 and damaged that building at the foot of Yucca Mountain. So that seismograph is still up there to keep track of all the earthquake activity.

Response
DOE recognizes that a seismic hazard exists at Yucca Mountain. But with the proper design, a repository could operate in compliance with the requirements of 40 CFR Part 197, *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada*. As discussed in Section 3.1.3.3 of the EIS, the Department has monitored earthquakes in the Nevada Test Site region since 1978. The site characterization program has investigated faults and earthquakes to assess seismic hazards at the site. Using the seismic hazard information, DOE would design repository facilities that are important to safety to withstand appropriate levels of ground motion and fault displacement. To the extent practical, the location of surface facilities would avoid faults that could rupture the surface. The seismic design requirements for the repository specify that structures, systems, and components that are important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (1 in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain. The Little Skull Mountain earthquake of 1992, Richter-magnitude 5.6, is the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain. That earthquake, with an epicenter 20 kilometers (12 miles) to the southeast, caused no damage at Yucca Mountain. The event did damage the Yucca Mountain Field Operations Center in Jackass Flat, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), but this facility was not built to the seismic-design specifications that are planned for the facilities at Yucca Mountain.

7.5.3.3 (7003)
Comment - EIS000402 / 0002
We are the third most earthquake state behind Alaska and California our neighbor on the west. How do you justify financially continuing the existing work with the earthquake tremors occurring almost daily. We, also, have had major earthquakes in the last couple of years in Southern California and in Western Nevada. No reports have been made to the media/public about the injuries/damage to the Yucca Mountain area or the cost to repair the damage. The [secrecy] deeply concerns me as it is almost like the 50's and the testing in southern Nevada, the deadly effects to us, lack of concern by the government and the appalling lying done.

How do you plan to financially deal with the continuing cost of damage by earthquakes and the resulting tremors? The lack of informing the public about the damage to people and Yucca Mountain dump?

Response
Because earthquake ground motions lessen with distance, the farther an earthquake occurs from Yucca Mountain, the larger it would have to be to contribute to the hazard at the site. At a distance of 100 kilometers (62 miles) from Yucca Mountain, earthquakes would have to reach an estimated magnitude of 8 to produce horizontal accelerations of 0.1*g*, where *g* is acceleration due to gravity (980 centimeters per second squared), at the site (DIRS 151945-CRWMS M&O 2000). The Little Skull Mountain earthquake of 1992, which is the largest recorded earthquake within 50 kilometers (31 miles) of Yucca Mountain (Richter magnitude 5.6), caused no damage at Yucca Mountain. It did damage the Yucca Mountain Field Operations Center in Jackass Flat, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), but this facility was not built to the seismic-design specifications planned for the facilities at Yucca Mountain. This earthquake caused less than $100,000 damage, although DOE spent additional funds on structural modifications to bring the building into compliance with existing codes. Earthquakes can disrupt power transmission, communications, roads, and rail lines. Tables 4-36 and 4-37 in the EIS present earthquake-accident scenarios that use an earthquake frequency of once in 50,000 years. This is roughly equivalent to a 7 magnitude on the Richter scale within 5 kilometers (3 miles) of Yucca Mountain, with a mean peak ground acceleration of 1.1*g* at the waste-emplacement depth. These are very

conservative calculations that give an indication of the maximum impact of such an event. Appendix H contains additional analysis of accidents due to seismic activity.

One of the primary objectives of DOE's characterization of the Yucca Mountain area is to identify faults with known or suspected Quaternary activity (during the past 1.6 million years) that could affect the design and performance of the repository. The identification and documentation of earthquakes occurring before recorded history is possible by studying the geologic record of past events. Larger events that ruptured the surface often leave geologic evidence in the form of offset strata and characteristic earthquake-related deposits. Geologic studies of fault-related deposits are the basis for identifying the occurrence of past large-magnitude, surface-rupturing displacements and evaluating their size, age, and occurrence rate.

In 1998, 25 experts from industry, academia, and government completed an extensive seismic hazard analysis of the Yucca Mountain area. These assessments indicate that the fault displacement hazard at Yucca Mountain is generally low. Results of long-term performance assessments of the subsurface repository indicated no significant effects on waste isolation from earthquakes. Using the seismic hazard information, the surface and underground facilities at Yucca Mountain are being designed to withstand ground motion from earthquakes. The analysis determined that an annual frequency of 1×10^{-4}, or the 10,000-year earthquake, is an appropriate level for preclosure design of structures that are important to safety. At Yucca Mountain, these structures would be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4}. For the 10,000-year earthquake, the design motions are dominated by the contribution of a normal-fault type earthquakes of magnitude 6.3 with an epicenter within 5 kilometers of Yucca Mountain that respond to higher structural frequencies.

The repository emplacement areas would be away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide release. Additional fault displacements and associated postemplacement seismic activity probably would be on existing fault planes.

DOE would build subsurface facilities in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have less effect on subsurface facilities than on surface facilities. Inspections of tunnels in the Yucca Mountain area revealed little evidence of disturbance following earthquakes. The subsurface facilities would be able to withstand the effects of earthquakes for the long-term performance of the repository. Sections 3.1.3.3 and 5.7.3 of the EIS contain more information.

7.5.3.3 (7075)
Comment - EIS000995 / 0004
Have the plans for shipment or storage for the huge amount of radioactive waste changed at all in light of the recent seismic activity in the area around Yucca Mountain?

Response
DOE has incorporated data from the recent earthquakes near Yucca Mountain in its seismic hazard assessments. With the proper design, a repository could operate safely and in compliance with *Environmental Radiation Protection Standards for Yucca Mountain, Nevada*, 40 CFR Part 197). As discussed in Section 3.1.3.3 of the EIS, the Department has monitored earthquakes in the Nevada Test Site region since 1978. The site characterization program has investigated faults and earthquakes to assess the seismic hazards at the site. Using this seismic hazard information, DOE would design repository facilities that are important to safety to withstand ground motion from earthquakes and fault displacements. To the extent practical, the location of such facilities would avoid faults that could rupture the surface. The seismic design requirements for the repository specify that structures, systems, and components important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years).

7.5.3.3 (7389)
Comment - EIS001957 / 0016
Section 3.1.3.2 Modern Seismic Activity – The narrative indicates that the DOE has monitored seismic activity associated with the Nevada Test Site since 1978. In the section on "Seismic Hazard," it is stated that:

"DOE based the design on ground motion and fault displacement that could be associated with future earthquakes at Yucca Mountain on the record of historic earthquakes in the Great Basin, evaluation of prehistoric earthquakes based on investigations of the faults at Yucca Mountain, and observations of ground motions associated with modern earthquakes...”

Later in this section, it is stated that:

“DOE needs to complete additional investigations of ground motion site effects before it can produce the final seismic design basis for the surface facilities.”

Further, it is stated in this same section that:

“A recent study...claims that the crustal strain rate in the Yucca Mountain area are at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. If higher strain rates are present, the potential volcanic and seismic hazards would be underestimated on the basis of the long-term geologic record. If the higher strain rates are confirmed, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.”

It would appear from these statements the DOE has potentially underestimated the potential volcanic and seismic hazards at the proposed site. The DOE acknowledges the need for additional studies before it is able to assess the effects of the earthquake hazard on the proposed repository. The NPS [National Park Service] is concerned what this deficiency might mean for the assessment of potential risks of release of radionuclides into the environment (specifically the regional ground-water flow system that underlies the proposed repository) and exposure to down gradient springs in Death Valley NP [National Park].

Response

DOE would base its design, in part, on input from the probabilistic seismic hazard assessment and from further evaluations of ground motion. The completed hazard studies provide probabilities of ground motion exceedance for different return periods. These results are in terms of ground motion in rock and are applicable to subsurface repository design.

DOE needs to complete geotechnical engineering investigations and ground motion studies before it can complete the designs of potential surface facilities. These data and analyses are necessary to determine ground motions at the foundation levels of the surface facilities for surface-facility foundation design. This does not affect the probabilistic hazard assessment for ground motion at the repository level or for fault displacement.

A March 1998 study of seismicity in the Yucca Mountain region (DIRS 103485-Wernicke et al. 1998) was based on baseline measurements using the Global Positioning System from 1991 through 1997 at five stations in the Yucca Mountain area. While the authors discussed the possible effects on their network from displacements associated with the June 1992 Little Skull Mountain earthquake, they did not correct the station-to-station distances for earthquake displacements.

In May 1998, scientists from the U.S. Geological Survey used the Global Positioning System to resurvey a network of 14 geodetic stations originally installed in 1983 (DIRS 118952-Savage, Svarc, and Prescott 1999) [DIRS 103485-Wernicke et al. (1998) used only 2 of the 14 stations in their study]. Based on the larger number of stations, the longer survey period (1983 to 1998), and the removal of the effects of the June 1992 Little Skull Mountain earthquake, the scientists concluded (DIRS 118952-Savage, Svarc, and Prescott 1999) that the strain rate in the Yucca Mountain region is significantly less (a factor of 20 or more) than the rate reported by Wernicke et al. (DIRS 103485-1998). The Geological Survey results are consistent with a large body of geologic and paleoseismological (fault-trenching investigations) data collected in the Yucca Mountain region over the past two decades.

Wernicke et al. (DIRS 103485-1998) speculated that magmatic inflation at depth could drive the high strain accumulation across the Yucca Mountain area. They pointed to an early seismic tomographic study by Oliver, Ponce and Hunter (DIRS 106447-1995) that hinted at the presence of a low-velocity zone beneath Crater Flat that could be consistent with basaltic magma. A subsequent study by Biasi (DIRS 105358-1996), based on more accurate seismic arrival times and a deeper inversion model than that used by Oliver, Ponce and Hunter (DIRS 106447-1995), demonstrated rather conclusively that there is no low-velocity zone under Crater Flat or Yucca Mountain that would suggest a major volcanic hazard.

DOE is continuing to fund investigations on crustal strain in the Yucca Mountain region through a cooperative agreement with the University of Nevada. Dr. Wernicke, the principal investigator of one study, recently estimated in a quarterly report to the DOE that conclusions from this study would be available in 2002. This study involves 30 geodetic monitoring sites with continuous Global Positioning System measurements, a significant improvement over the Wernicke et al. (DIRS 103485-1998) study.

7.5.3.3 (7460)
Comment - EIS001969 / 0012
Pages S-37, 5.4.1.3 [S.4.1.3] Geology, first paragraph.

Point (3) states that the Topopah Spring Tuff was chosen because of "...its location away from major faults that could adversely affect the stability of underground openings..." This statement implies that the Topopah Spring Tuff is not intersected by major faults, which it most assuredly is. Faults cut through all of the Tertiary volcanic units in the proposed repository area, including the Topopah Spring Tuff. Solitario Canyon fault and several other known faults cut through the Topopah Spring Tuff, some immediately adjacent to the underground facilities.

The relationship between faulting and the selection criteria of the Topopah Spring Tuff as the repository host rock in the Summary and the Draft EIS itself (page 3-24) is unclear and needs more detailed and accurate explanation. The selection of Topopah Spring Tuff cannot be predicated on its lack of proximity to seismically active faults. If so, the site would not be viable. Clarification is needed.

Response
DOE agrees that it cannot predicate its selection of the Topopah Spring Tuff for the repository on the lack of proximity to seismically active faults. The Department has changed the statement in the Summary and Section 3.1.3 of the EIS to indicate that it chose the repository emplacement area because of its location away from major faults that could adversely affect the stability of underground openings.

7.5.3.3 (7464)
Comment - EIS001969 / 0013
Page S-37, second paragraph.

The statement, "The Solitario Canyon fault forms the major bounding fault on the west side of Yucca Mountain, and volcanic units in the mountain tilt eastward as a result of displacement along this and lesser faults through the mountain...," needs clarification. There are faults on the east side of Yucca Mountain. The faults that bound the eastern side of the proposed repository area, the Bow Ridge and Paintbrush Canyon faults, to name just two (see Table 3-8, Characteristics of major faults at Yucca Mountain, v. 1 -Impact Analysis, Draft EIS), need to be mentioned here. Additionally, because these latter two north-trending faults dip to the west beneath the repository area and the adjacent material handling facilities that would be built at the north and south portals, understanding the seismic hazard potential of these faults is extremely important.

In addition, easterly tilts are not the result of movement on the Solitario Canyon fault and "lesser faults through the mountain." These tilts are the result of movement on a whole series of block-bounding faults, of which the Solitario Canyon fault is one.

Response
The comment is correct that the Solitario Canyon fault is not the only block-bounding fault identified in the EIS. However, DOE did not modify the text of the Summary in order to keep it understandable to a wide range of readers. DOE has, however, clarified the text in Section 3.1.3.2 of the EIS, which also refers readers to numerous reference materials on the subject.

7.5.3.3 (7520)
Comment - EIS001969 / 0025
Page 3-25, Section 3.1.3.2 Geologic Structure, fifth paragraph.

It is stated here that the "...total estimated displacement on the most active block-bounding faults...during the past 1.6 million years is less than 50 meters...(Simonds and others, 1995)." This statement is from the Conclusion section of Simonds and others (1995) and is misleading when taken out of context. All measurements of Quaternary (1.6 Ma to present) displacement on these faults range from 0 to 6 m with most displacement in the 1-2.5 m range, as reported in Table 2 of Simonds and others (1995). Reference Table 3-8 in this paragraph to help clarify this point.

Response
DOE has clarified this paragraph in Section 3.1.3.2 of the EIS, as suggested by the comment.

7.5.3.3 (7529)
Comment - EIS001969 / 0026
Page 3-25, Section 3.1.3.2 Geologic Structure, sixth paragraph.

The statement, "The Solitario Canyon fault along the west side of Yucca Mountain is the major block-bounding fault...," is incorrect. The Solitario Canyon fault is one of numerous block-bounding faults that are shown on Figure 3-10. These include the Northern Windy Wash, Fatigue Wash, Solitario, Iron Ridge, Dune Wash Bow Ridge, Midway Valley, Paintbrush Canyon faults, just to name those within 4 km radius of the proposed perimeter of the repository.

Response
The comment is correct; text in Section 3.1.3.2 has been revised for clarity. The Solitario Canyon fault is not the only block-bounding fault identified.

7.5.3.3 (7536)
Comment - EIS001969 / 0027
Page 3-25, Section 3.1.3.2 Geologic Structure, last paragraph.

This short treatment of intra block faults (the subsidiary faults between the block bounding faults) places undue emphasis on NW-trending faults by discussing them first. Within the central block, where the repository would be sited, the intra block faults with the longest map traces and the largest amounts of displacement are the Ghost Dance Fault (splitting the center of the block) and the block-margin faults ("Imbricate Zone" of Scott, 1990) that are just west of the Bow Ridge Fault. Day and others (1998, USGS Map I-2601) and Scott and Bonk (1984) also document this. The NW-trending faults, such as the Sundance Fault, though characterized correctly, are relatively minor in comparison (Potter and others, USGS OFR 98-266, in press). It would be more appropriate to mention the much larger Ghost Dance fault first.

Response
DOE has reorganized the paragraph in question to discuss the Ghost Dance fault, which occurs in the middle of the repository block, before discussing the northwest-trending faults.

7.5.3.3 (7538)
Comment - EIS001969 / 0028
Page 3-26, Figure 3-9, Types of geologic faults.

For clarity, definitions of normal and reverse faults need to uniquely specify the correct sense of motion. For a normal fault reword the description, "dip-slip fault where one block has moved downdip relative to the other," to "dip-slip fault where the upper block has moved downdip relative to the lower block." For reverse fault, reword "dip-slip fault where one block has moved updip relative to the other" to "dip-slip fault where the upper block has moved updip relative to the lower block."

A diagram is needed for low-angle normal faults, such as in Calico Hills east, and Bare Mountain west, of Yucca Mountain.

Response
The description of faults in Figure 3-9 of the Final EIS has been clarified.

7.5.3.3 (7573)
Comment - EIS001969 / 0032
Page 3-30, fifth paragraph.

The correct statement is that there is no observable strain measured within the error of the data.

Response
DOE believes the paragraph is correct as written. The main point of this paragraph is that the strain rate is significantly less than the rate reported by Wernicke et al. (DIRS 103485-1998), which did not account for the coseismic and postseismic effects of the 1992 Little Skull Mountain earthquake.

7.5.3.3 (8148)
Comment - EIS000817 / 0082
P. 3-29 -- The 1992 Little Skull Mt. earthquake is proof of modern seismic activity. Wernicke's study in "Science" magazine 1998 shows concerns of accuracy of your studies. I predict you have, in fact, underestimated potential volcanic and seismic hazards. And, frankly, I don't see why this issue isn't given main priority for it could halt everything. Why aren't your ground motion site effects studies done before you put out this draft EIS? You need to reassess this before you go further, and it should have been done by now.

Response
The geodetic study reported in the March 1998 issue of *Science* (DIRS 103485-Wernicke et al. 1998) was based on measurements from 1991 through 1997 at five stations in the Yucca Mountain area using the Global Positioning System. While the authors discussed the possible effects on their network from displacements associated with the June 1992 Little Skull Mountain earthquake, they did not correct the station-to-station distances for earthquake displacements.

In May 1998, scientists from the U.S. Geological Survey used the Global Positioning System to resurvey a network of 14 geodetic stations originally installed in 1983. Wernicke et al. (DIRS 103485-1998) used two of the 14 stations in their study. Based on the larger number of stations, the longer survey period (1983 to 1998), and the removal of the effects of the June 1992 Little Skull Mountain earthquake, the U.S. Geological Survey scientists concluded (DIRS 118952-Savage, Svarc, and Prescott 1999) that the strain rate in the Yucca Mountain region is significantly less (by a factor of 20 or more) than the rate reported by Wernicke et al. (DIRS 103485-1998). The results of the U.S. Geological Survey are consistent with a large body of geologic data and fault-trenching investigations in the Yucca Mountain region over the past two decades.

Wernicke et al. (DIRS 103485-1998) speculated that magmatic inflation at depth could be the cause of the high strain accumulation across the Yucca Mountain area. They pointed to an early seismic tomographic study by Oliver, Ponce, and Hunter (DIRS 106447-1995) that hinted at the presence of a low-velocity zone beneath Crater Flat that could be consistent with basaltic magma. A subsequent study (DIRS 105358-Biasi 1996), based on more accurate seismic arrival times and a deeper inversion model, demonstrated rather conclusively that there is no low-velocity zone under Crater Flat or Yucca Mountain that would suggest a major volcanic hazard.

With regard to ground motion studies, as discussed in Section 3.1.3.3 of the EIS, DOE has been monitoring earthquakes in the Nevada Test Site region since 1978. Faults and earthquakes have been investigated as part of the site characterization program to assess seismic hazards at the site. DOE recognizes that the effect of earthquakes on a repository at Yucca Mountain is a major concern and we have conducted extensive analysis. The EIS analyzes the probability of earthquake occurrence and the consequences to the repository and the environment. To support this analysis, DOE and the USGS first completed a comprehensive evaluation of the seismic hazards in the Yucca Mountain region using standard practices of mapping, trenching, age dating, and monitoring of contemporary seismicity. Then DOE-sponsored groups of experts from within and outside the Project used these site data to assess the seismic hazard potential of all significant seismic sources in the Yucca Mountain region. Another group of experts used numerical modeling methods and data from recent earthquakes to estimate ground motion attenuation relationships that are appropriate for Yucca Mountain.

Using this seismic hazard information, repository surface facilities would be designed to withstand the effects of earthquakes that might occur during the lifetime of the facilities. The seismic design requirements for the repository specify that structures, systems, and components that are important to safety would be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

Subsurface facilities would be built in solid rock, and because vibratory ground motion decreases with depth, earthquakes would have less an affect on subsurface facilities than surface facilities. Inspection of existing tunnels in the Yucca Mountain area has revealed little evidence of disturbance following earthquakes. The subsurface facilities would also be designed to withstand the effects of earthquakes for the long-term performance of the repository.

7.5.3.3 (8443)
Comment - EIS001397 / 0011
In the third most seismically active place on the North American Continent, the issues of earthquakes and land drift are extremely important. They are glossed over in this DEIS. There are 32 fault lines near Yucca Mountain. This DEIS shows tunnels drilled through them, next to them, and with fault lines ending within tunnel structures. The Earth tried to make an obvious point in June of 1992 when over 1.25 million dollars of damage was sustained to the building for the project research at Yucca Mountain. Since then hundreds of earthquakes of significant magnitude have occurred in the immediate area. The final EIS must adequately address this important concern.

Recent satellite research indicates that the earth is moving apart in the Yucca Mountain region at the rate of six inches every hundred years, or 50 feet over the 10,000 year lifespan of this project. A whole lot of casks could fall into a 50 foot chasm, or even serious shift and risk breaching with six inches of motion. Recent research that will not be finished for several years indicates hot water flow upward through the mountain. This, combined with earth crust movement, may indicate that Yucca Mountain is actually directly over a magma pocket. This DEIS does not adequately address these concerns at all. Full information must be made available, reviewed by the public after that time, and then considered in its entirety for potential licensing of this facility.

Response
DOE agrees that earthquake occurrence in the context of plate tectonics is an important consideration. The Department recognizes there is a seismic hazard at Yucca Mountain, but with the proper design a repository could operate safely and provide adequate long-term performance. As discussed in Section 3.1.3.3 of the EIS, the Department has monitored earthquake activity in the Nevada Test Site region since 1978. The site characterization program has investigated faults and earthquakes to provide information needed to assess seismic hazards at the site. Using the seismic hazard information, DOE would design repository facilities important to safety to withstand appropriate levels of ground motion and fault displacement. To the extent practical, the location of such facilities would avoid faults that could produce surface displacement. The seismic design requirements for the repository specify that structures, systems, and components important to safety would be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (1 in 10,000 years). The results of the seismic hazard analysis for Yucca Mountain indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

The 1992 Little Skull Mountain magnitude 5.6 earthquake is the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain. The epicenter was 20 kilometers (12 miles) to the southeast of the site and caused no damage at Yucca Mountain. DOE built the facilities in Jackass Flat that were damaged in that earthquake, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility), in the 1960s and did not design them to accommodate the levels of ground motion for which it would design repository facilities. Section 3.1.3.3 of the EIS contains more information.

As part of site characterization activities, DOE monitors the seismic activity in the Yucca Mountain region. Since 1975, more than 1,500 earthquakes with magnitudes greater than 2.5 have occurred within 80 kilometers (50 miles) of the site, including the Little Skull Mountain earthquake. Some small-magnitude events (about 2.5 magnitude) are attributed to the Little Skull Mountain earthquake. Other small-magnitude events might not represent an increase in seismicity but rather the greater sensitivity of new instrumentation.

In May 1998, U.S. Geological Survey scientists conducted a reassessment of crustal strain and published their findings in the Journal of Geophysical Research (DIRS 118952-Savage, Svarc, and Prescott 1999). The principal strain rates determined over the 1983-1998 survey interval, confirmed previous analyses, and were significantly less than reported by Wernicke et al. (DIRS 103485-1998). The scientists concluded that the residual strain rate in the Yucca Mountain area is not significant at the 95-percent confidence level after removal of effects of the 1992 Little Skull Mountain earthquake and the strain accumulation on faults in Death Valley.

DOE is continuing to fund additional investigations on the regional crustal strain rate in the Yucca Mountain region as specified in a cooperative agreement with the University of Nevada. Dr. Wernicke, the principal investigator of one study, recently estimated in a quarterly report to the DOE that conclusions from this study would be available in 2002. The Department will report the conclusions as they become available. If the higher crustal strain rates were confirmed, DOE would reassess the volcanic and seismic hazard at Yucca Mountain.

Dublyansky (DIRS 104875-1998) proposed another line of data in support of the warm water upwelling hypothesis. This study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. The report concludes that some of the crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of scientists with expertise in hydrology, geology, isotope geochemistry, and climatology did not concur with the conclusions in the report (DIRS 100086-Stuckless et al. 1998). Although DOE has disagreed with the central scientific conclusions in this report, it agreed to support continuing research. An independent investigation by Jean Cline, University of Nevada, Las Vegas, will be completed in Fiscal Year 2001. Section 3.1.4.2.2 of the EIS contains more information.

DOE agrees that full information must be made available to the public. The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000) contains more complete technical information. By definition, the licensing process must consider all available information.

7.5.3.3 (8586)
Comment - EIS001256 / 0005
Our original comments expressed concern about geologic stability, citing the earthquake event of October 1999. Now it comes to our attention that there is a theory being investigated by scientists that predicts earthquakes as large as 7.0 or 8.0 on the Richter scale that could be located as near as 20 miles from Yucca Mountain. The siting of Yucca Mountain is being called into question more vigorously every day.

Response
As described in Section 3.1.3.3 of the EIS, the largest recorded earthquake within 50 kilometers (30 miles) of Yucca Mountain was the Little Skull Mountain event in 1992 with a magnitude of 5.6. This event occurred about 20 kilometers (12 miles) southeast of Yucca Mountain. Based on many studies of current and past seismicity, the surface facilities at the repository would be designed to withstand an earthquake with a Richter-scale magnitude of 6.3 that would occur within 5 kilometers (3 miles) of Yucca Mountain. Because vibratory ground motion from earthquakes decreases with depth, earthquakes would have less of an effect on subsurface facilities than on surface facilities.

7.5.3.3 (8700)
Comment - EIS001660 / 0053
Ongoing seismic studies being conducted for the Yucca Mountain region by the University of Nevada and seismic studies for each of the 10 affected counties should be completed before DOE makes a decision whether to recommended Yucca Mountain as a geologic repository.

Response
Section 3.1.3.3 of the EIS incorporates the best, most recent information that was available at the time the document was prepared. To analyze the probability of occurrence and the consequences from earthquakes at Yucca Mountain, DOE and the U.S. Geological Survey first completed a comprehensive evaluation of the seismic hazards in the Yucca Mountain region using standard practices of mapping, trenching, age-dating, and monitoring of contemporary seismicity. DOE then convened groups of experts from within and outside the Yucca Mountain Site Characterization Project to assess the seismic hazard of all significant seismic sources in the Yucca Mountain region. Another group

of experts used numerical modeling methods and data from recent earthquakes to estimate ground motion attenuation relationships that are appropriate for Yucca Mountain.

The expert assessments concluded that the fault-displacement hazard is low. Assessment of the long-term performance of the repository indicated that earthquakes would not significantly affect waste isolation. Using the seismic hazard information, surface facilities would be designed to withstand the effects of earthquakes that might occur during the lifetime of the facilities. The seismic design requirements for the repository specify that structures, systems, and components that are important to safety must be designed to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (1 in 10,000 years). The seismic design basis would continue to be updated, as necessary.

7.5.3.3 (8787)
Comment - EIS001671 / 0003
Hasn't anyone noticed the change in the earth movements? If we get earthquakes results, your concrete, around the cask full of waste, it will break, then what?

Response
DOE recognizes there is a seismic hazard at Yucca Mountain, but with the proper design a repository can operate safely. Site characterization activities include studies to quantify the seismic hazard so that facilities that are important to safety can be designed to withstand maximum ground motions and fault displacement.

There are no plans to encase the waste packages in concrete. Section 2.1.2.2.4.1 of the EIS describes the design of the waste package. This design incorporates the potential for an earthquake-induced rockfall from the ceiling of the repository. The *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998) considers repository performance at 10,000-, 100,000- and 1-million-year periods. Over 10,000 years, the probability of an earthquake-induced rockfall causing a waste package to split open is almost zero because the waste package would be thick enough to withstand the impact from most slabs of rock. There is less than a 1-percent probability that falling rocks would accelerate corrosion during this period. Over 1 million years, earthquake-induced rockfalls could breach about 30 percent of the waste packages in the repository. When added to expected failures from corrosion, these rock-induced failures would not produce a major change in the overall probability of failure because most would occur after 500,000 years (DIRS 101779-DOE 1998).

In addition, the waste emplacement areas would be away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide releases.

7.5.3.3 (8826)
Comment - EIS000869 / 0007
The site at Yucca Mountain is very precarious due to the increasing number and severity of earthquakes in the southern California, southern Nevada and even Yucca Mountain areas. Regarding S.4.1.3 Geology, in the draft Environmental Impact Statement, paragraph 4 on page S-37 states that the 5.6 earthquake in 1992 caused no detectable damage ... at the Yucca Mountain site. This is a false statement as there was significant damage to some buildings at the Yucca Mountain site. If one of those buildings had been the nuclear waste transfer area, it could have the potential to create a nuclear nightmare for surrounding communities including southern Nevada, southern Utah, and possibly, areas of southern California. At the present time, these are relatively low populated areas, but all the potentially affected areas are experiencing phenomenal growth in population and tourism. The draft summary repeatedly references a population of about 28,000 within 80 kilometers (50 miles) of the Yucca Mountain site. However, when the population within 100 miles of the Yucca Mountain site is considered, as it should be, the number of population would increase dramatically. If there were an accidental exposure via air or water, it would definitely impact many more people that the 50-mile radius claims.

Response
There is no evidence to suggest that the number and severity of earthquakes in the Yucca Mountain area and adjacent southern California is increasing. Recent earthquakes at Scottys Junction, Nevada [August 1, 1999, magnitude 5.7, approximately 80 kilometers (50 miles) from Yucca Mountain], and at Hector Mine, California [October 16, 1999, magnitude 7.1, approximately 250 kilometers (155 miles) from Yucca Mountain], had no effect at Yucca Mountain. Recordings of these events at Yucca Mountain indicated ground motions that were more than

10 times smaller than the seismic design to which the surface facilities at Yucca Mountain would be constructed. The Scottys Junction earthquake had a magnitude, depth, and normal focal-plane solution similar to those recorded for the Little Skull Mountain earthquake in 1992, which at 5.6 on the Richter scale is the largest earthquake recorded within 50 kilometers (30 miles) of Yucca Mountain. The Little Skull Mountain earthquake, with an epicenter 20 kilometers (12 miles) to the southeast, caused no damage at Yucca Mountain. It did damage the Yucca Mountain Field Operations Center in Jackass Flat, approximately 2 kilometers (1.2 miles) from the epicenter (about 4 miles from the Exploratory Studies Facility). That facility was not built to the seismic design specifications planned for the facilities at Yucca Mountain.

The seismic design requirements for the repository specify that structures, systems, and components important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis indicate that this is the equivalent of about a magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain.

DOE would build the subsurface facilities in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have less of an effect on subsurface facilities than on surface facilities. Inspections of existing tunnels in the Yucca Mountain area have revealed little evidence of disturbance following earthquakes. In addition, DOE would design the subsurface facilities to withstand the effects of earthquakes for the long-term performance of the repository. Section 3.1.3.3 of the EIS contains more information.

The 80-kilometer (50-mile) radius is the established precedent for calculating the potential population (collective) dose around a nuclear facility. Potential impacts from all accident scenarios to the population beyond 80 kilometers would be negligible.

7.5.3.3 (9073)
Comment - EIS001936 / 0003
We are concerned that a March 1998 study by the Nuclear Regulatory Commission showed that the ground around Yucca Mountain could stretch over three feet in the next 1,000 years. This movement could crush any canisters of waste buried there, exposing a wide area of the Southwest to deadly radiation. Earthquakes and volcanism in the area could also disturb the canisters.

Response
Based on the results of analyses reported in Chapter 5 of the EIS concerning the long-term performance of the repository, which considered the effects of future seismic and volcanic activity, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with 40 CFR Part 197). Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region.

The 1998 study referred to by the commenter is probably the article published in *Science* magazine (DIRS 103485-Wernicke et al. 1998) that concludes that crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than would be predicted from the tectonic history of the area. The authors speculated that higher strain rates indicate that the potential volcanic and seismic hazards are underestimated based on the long-term geologic record. U.S. Geological Survey scientists (DIRS 118952-Savage, Svarc, and Prescott 1999) reported that all geodetic surveys indicated no large strain accumulation and therefore do not support the claims of Wernicke et al. (DIRS 103485-1998).

DIRS 103485-Wernicke et al. (1998) was based on measurements using the Global Positioning System (GPS) over the period from 1991 to 1997 at five stations in the Yucca Mountain area. While the authors discussed the possible effects on their network from displacements associated with the June 1992 Little Skull Mountain earthquake, they did not correct the station-to-station distances for earthquake displacements.

In May 1998, scientists from the U.S. Geological Survey resurveyed (also using the Global Positioning System) a network of 14 geodetic stations that was originally installed in 1983 (DIRS 118952-Savage, Svarc, and Prescott 1999). [Only two of the 14 stations were used by Wernicke et al. (DIRS 103485-1998) in their study.] Based on the greater number of stations, the longer survey period (1983 to 1998), and the removal of the effects of the June 1992 Little Skull Mountain earthquake, the Survey scientists concluded (DIRS 118952-Savage, Svarc, and Prescott 1999) that the strain rate in the Yucca Mountain region is significantly less (a factor of 20 or more) than the rate reported by Wernicke et al. (DIRS 103485-1998). The Survey results are consistent with a large body of geological and paleoseismological (fault-trenching investigations) data that have been collected in the Yucca Mountain region during the past two decades.

Wernicke et al. (DIRS 103485-1998) speculated that the high strain accumulation across the Yucca Mountain area could be driven by magmatic inflation at depth. They pointed to an early seismic tomographic study by Oliver, Ponce, and Hunter (DIRS 106557-1995) that hinted at the presence of a low-velocity zone beneath Crater Flat that could be consistent with basaltic magma. A subsequent study (DIRS 105358-Biasi 1996), based on more accurate seismic arrival times and a deeper inversion model than that used by Oliver, Ponce, and Hunter (DIRS 106557-1995), demonstrated rather conclusively that there is no low-velocity zone (such as a magma pocket) under Crater Flat or Yucca Mountain that would suggest a major volcanic hazard.

Section 4.1.8 of the EIS describes the impacts from accident scenarios associated with earthquakes during operation of the repository. Several sections in Chapter 5 of the EIS consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. Except for some factual changes and clarifications that have been included in the Final EIS, DOE believes that the information in the Draft EIS on geology, geologic hazards, and the effects of these hazards on the repository have been adequately described and analyzed.

With regard to the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 explains how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3.3 (9248)
Comment - EIS001684 / 0004
Why has the DOE selected a site (Yucca Mountain) that is seismically unstable?

Response
In 1987, Congress selected Yucca Mountain as a potential location for a monitored geologic repository, and directed DOE to determine whether the site is suitable. Some of the reasons that Congress selected Yucca Mountain for study included a deep water table, favorable geology, a desert environment, and the fact that the Nevada Test Site was already a controlled area.

7.5.3.3 (10114)
Comment - EIS002155 / 0003
Secondly, seismic activity. Why in God's name would we pick the most active seismic state to put the waste?

Response
In 1987, Congress selected Yucca Mountain as a potential location for a monitored geologic repository, and directed DOE to determine if the site is suitable. Some of the reasons Congress selected Yucca Mountain for study included a deep water table, favorable geology, a desert environment, and the fact that the Nevada Test Site was already a controlled area.

It is true that Nevada ranks third, behind Alaska and California, in seismic activity. Its reputation as a highly active state comes from major historic earthquakes in western Nevada with magnitudes greater than 7 on the Richter scale. Yucca Mountain does not lie within this highly active seismic belt.

Based on the results of analyses reported in Chapter 5 of the EIS concerning the long-term performance of the repository, which considered the effects of future seismic and volcanic activity, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with 40 CFR Part 197. Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 of the EIS describes the impacts from accident scenarios associated with earthquakes during operation of the repository. Several sections in Chapter 5 of the EIS consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository.

7.5.3.3 (10452)
Comment - EIS002126 / 0002
Newsweek January 31st, 1994 quoted the Southern California Research Earthquake Center, which consists of geologists from Caltech, the USGS, UCLA, U.S.C. and they predict that LA is overdue for an earthquake 125 times as strong as the one they had in 1994.

Science Magazine January 13th, '95 quoted four articles presented from a symposium at Caltech and they -- the consensus was that LA would have had to have had a 6.7 earthquake every eleven years for the past 200 years not to be overdue for earthquakes in the 7s, and once it's in that category, it could go from one fault system to another causing more 7s. That could be like fifteen 7s plus, and for a hundred miles around, and when you read the footnotes, it says they've underestimated the probabilities and dangers in every case and also that they have not included the San Andreas in their scenario. And how would this impact on the solidity of the land above and below the Yucca Mountain site and on the casks themselves? I knew about the potential earthquakes when I bought my house in Henderson, but the nuclear waste is another thing.

Response
Repository facilities that are important to safety would be designed to withstand ground motion from a Richter-scale magnitude 6.3 earthquake with an epicenter within 5 kilometers (3 miles) of Yucca Mountain and from a magnitude 7.5 earthquake or greater in Death Valley within 50 kilometers (31 miles) of Yucca Mountain.

While large earthquakes are possible in the region surrounding Yucca Mountain, geologic evidence does not support the view that any would be as large as the largest that can occur along the San Andreas Fault system in southern California. In addition, the recurrence interval for large earthquakes near Yucca Mountain is longer than the recurrence interval for large earthquakes along the San Andreas Fault system.

DOE's seismic hazard assessment incorporated all pertinent information on earthquake sources that might affect Yucca Mountain. Most earthquake sources are closer to the site than Los Angeles. Seismicity in the Los Angeles area, no matter how intense, is unlikely to affect the seismic hazard at the Yucca Mountain site because Los Angeles is so far away.

7.5.3.3 (11844)
Comment - EIS001788 / 0001
A 21 year study tells us much about the structure of Yucca Mountain, but does not tell us when earthquakes will happen there, exactly where they will happen or how they will change the rocks and fissures that exist. Since 1910 there have been over 600 earthquakes of greater than magnitude 2.5 within a 50 mile radius of Yucca Mountain. How many earthquakes will happen within 50 miles of Yucca Mountain before 1,000 years is over? This basin area is a dynamic area.

Response
Based on the results of analyses on the long-term performance of the repository (Chapter 5 of the EIS), which considered the effects of future seismic and volcanic activity, DOE believes that a repository at Yucca Mountain would operate safely (in compliance with 40 CFR Part 197). Section 3.1.3 describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including faults, seismicity, and the volcanic history of the region. Section 4.1.8 describes the impacts from accident scenarios associated with earthquakes during the operation of the repository. Several sections in Chapter 5 consider earthquakes and volcanic eruptions and their effects on the long-term performance of the repository. DOE believes that the information in the EIS adequately describes and analyzes the geology, geologic hazards, and the effects of these hazards on the repository.

With regard to the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 of the EIS explains how DOE dealt with these issues. Briefly, DOE acknowledges that it is not possible to predict with certainty what will occur thousands of years into the future. The National Academy of Sciences, the Environmental Protection Agency, and the Nuclear Regulatory Commission also recognize the difficulty of predicting the behavior of complex natural and engineered barrier systems over long time periods. The Commission regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the Environmental Protection Agency has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

DOE, consistent with recommendations of the National Academy of Sciences, has designed its performance assessment to be a combination of mathematical modeling, natural analogues, and the possibility of remedial action in the event of unforeseen events. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic and engineered components of the disposal system and relies on:

1. Results of extensive underground exploratory studies and investigations of the surface environment.

2. Consideration of features, events and processes that could affect repository performance over the long-term.

3. Evaluation of a range of scenarios, including the normal evolution of the disposal system under the expected thermal, hydrologic, chemical and mechanical conditions; altered conditions due to natural processes such as changes in climate; human intrusion or actions such as the use of water supply wells, irrigation of crops, exploratory drilling; and low probability events such as volcanoes, earthquakes, and nuclear criticality.

4. Development of alternative conceptual and numerical models to represent the features, events and processes of a particular scenario and to simulate system performance for that scenario.

5. Parameter distributions that represent the possible change of the system over the long term.

6. Use of conservative assessments that lead to an overestimation of impacts.

7. Performance of sensitivity analyses.

8. Use of peer review and oversight.

DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts associated with the ability of the repository to isolate waste over thousands of years.

7.5.3.3 (12035)
Comment - EIS000540 / 0007
Frequent seismic events in the proximity of both sites make it impossible to predict the protection of the public's health and safety from the risk of radioactive release (621 earthquakes greater than 2.5 within a 50-mile radius since 1976;[4] and

Recognizing that this level of seismic activity exceeds current Nuclear Regulatory Commission regulations for allowing licensure as a nuclear reactor with on-site waste storage.[5]

[4]Nevada Agency for Nuclear Projects. Earthquakes: magnitude 2.5 and Greater in the Vicinity of the Proposed Yucca Mountain Nuclear Waste Storage and Disposal Sites from 1976-1996. (Data Source: Council of the National Seismic System Composite Catalog, 1976 to present, Southern Great Basin Seismic Network) *Nevada Nuclear Waste Policy News*, Volume 7, Issue 1. Carson City, Nevada, July 1997.

[5]Nuclear Regulatory Commission. 10 CFR 100: Reactor Site Criteria. *Federal Register*, Washington, DC, December 11, 1996.

Response
DOE completed an extensive seismic-hazard analysis involving 25 experts from industry, academia, and government in 1998. The expert assessments indicated that the fault-displacement hazard at Yucca Mountain is generally low. Results of long-term performance assessments of the subsurface repository indicated no significant effects on waste isolation from earthquakes.

DOE would design the surface and subsurface facilities at Yucca Mountain to withstand ground motion from earthquakes. The analysis determined that an annual frequency of 1×10^{-4}, or the 10,000-year earthquake, is an appropriate level for preclosure design of structures that are important to safety. At Yucca Mountain, DOE would design these structures to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4}. For the 10,000-year earthquake, design motions would be dominated by the contribution of a normal-fault type earthquake of magnitude 6.3 with an epicenter within 5 kilometers (3 miles) of Yucca Mountain that responded to higher structural frequencies. At lower frequencies, contributions from strike-slip type earthquakes of magnitude 7.5 or greater events in Death Valley [50 kilometers (31 miles) distance] are important contributors to ground motions. The analyses include uncertainties in the magnitude and location of the earthquakes. DOE regards this annual frequency as appropriate and conservative because it reflects the annual probabilities of design ground motions for nuclear powerplants in the western United States. In addition, surface facilities at Yucca Mountain would pose a lower risk than nuclear powerplants.

7.5.3.3 (12328)
Comment - EIS001957 / 0009
Adequate discussion is not provided in the draft EIS regarding the proposed repository container's vulnerability to damage from seismic disturbances (i.e., earthquake hazards) common to this area. We recommend the Department of Energy obtain from the U.S. Geological Survey the predicted earthquake scenario for this area, over the next century at a minimum. The NPS [National Park Service] is concerned that any seismic damage may contribute to potential release of radionuclides into the environment (specifically the regional ground-water flow system that underlies the proposed repository) and thence discharged at down-gradient springs (specifically water flows in Death Valley NP [National Park]).

Response
The EIS analyzes the probability of occurrence and the potential environmental impacts from earthquakes at the proposed repository. To support this analysis, DOE and the U.S. Geological Survey completed a comprehensive evaluation of the seismic hazards in the Yucca Mountain region using standard practices of mapping, trenching, age-dating, and monitoring contemporary seismicity. Then DOE-sponsored groups of scientific experts from inside and outside the Yucca Mountain Site Characterization Project used the site data to assess the seismic hazard potential of all significant seismic sources in the Yucca Mountain region. Another group of experts used numerical modeling methods and data from recent earthquakes to estimate ground motion attenuation relationships appropriate for Yucca Mountain.

The expert assessments indicated that the hazard associated with fault displacements is generally low. Results of long-term performance assessments of the repository indicated no significant effects on waste isolation from earthquakes. Calculations show that there would be almost no effect on repository performance from rockfalls. Section I.2.1.7 of the EIS discusses the updated waste package design and the vulnerability of drip shields to damage from seismic disturbances.

Using the seismic hazard information, DOE would design repository surface facilities to withstand the effects of earthquakes that could occur during the lifetime of the facility. The seismic design requirements for the repository specify that structures, systems, and components that are important to safety must be able to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4} (once in 10,000 years). The results of the seismic hazard analysis indicate that this is the equivalent of an earthquake with a magnitude of about 6.3 located about 5 kilometers (3 miles) from Yucca Mountain.

DOE would build the subsurface facilities in solid rock. Because vibratory ground motion decreases with depth, earthquakes would have less effect on subsurface facilities than on surface facilities. Inspection of tunnels in the Yucca Mountain area has revealed little evidence of disturbance following earthquakes. In addition, DOE would design the subsurface facilities to withstand the effects of earthquakes for the long-term performance of the repository. The emplacement areas would be in areas away from faults that could adversely affect the stability of the underground openings or act as pathways for water flow that could lead to radionuclide releases. Additional fault displacements from postemplacement seismic activity probably would be on existing fault planes. Section 3.1.3.3 of the EIS contains more information.

7.5.3.3 (12405)
Comment - EIS001888 / 0377
[Clark County summary of comments it has received from the public.]

Many commenters asked that the EIS evaluate the impacts of seismicity, geologic structure, and volcanism on radionuclide containment and repository operations. Issues raised for consideration included: (1) the proximity of Yucca Mountain to the Walker Lane/Las Vegas Shear Zone, (2) the relationship between the Walker Lake/Las Vegas Shear Zone and the San Andreas fault, (3) the pattern of earthquakes and volcanism in the region, (4) the classification of the region as a high earthquake-hazard zone, (5) and active plate tectonics. Several commenters stated that the faults at Yucca Mountain need additional study for inclusion in the EIS, because they are pathways (through rupture or breach) for gases and fluids to enter and exit the repository and transport radionuclides. Some commenters questioned the reliability of predicting the size and location of earthquakes, and the accuracy and recency of geologic mapping in the region. Others wanted a detailed description of the seismic design of the facility, and an evaluation of the consequences from the largest credible earthquake, including changes in the water table. One commenter said that large volcanic eruptions have covered Yucca Mountain and asked that the EIS examine the likelihood of similar eruptions in the future.

Response
In 1998, 25 experts from industry, academia, and government conducted a seismic hazard analysis at Yucca Mountain. The experts assessed the potential hazard at Yucca Mountain from vibratory ground motion from possible earthquakes along local and regional faults. The assessment was based on available geologic, paleoseismic, historic seismicity, and geophysical data. The experts also assessed the hazard at Yucca Mountain from displacement on local faults.

DOE is designing the surface and underground facilities at Yucca Mountain to withstand ground motion from earthquakes that were identified in the seismic hazard analysis. The analysis determined that an annual frequency of 1×10^{-4} (the 10,000-year earthquake) is an appropriate level for preclosure design of structures that are important to safety; so DOE would design these structures to withstand horizontal ground motion with an annual frequency of occurrence of 1×10^{-4}. For the 10,000-year earthquake, ground motions are likely to be dominated by the contribution of a normal-fault earthquake of Richter magnitude 6.3 with an epicenter within 5 kilometers (3 miles) of Yucca Mountain that responds to higher structural frequencies. At lower frequencies, contributions from strike-slip earthquakes of magnitude 7.5 or greater in Death Valley [50 kilometers (31 miles) away] are important contributors to ground motions. DOE regards this annual frequency to be appropriate and conservative because it reflects the annual probabilities of ground motions for nuclear powerplants in the western United States. The annual frequency of 1×10^{-4} is more conservative than the nuclear powerplants that the Nuclear Regulatory Commission has licensed, and the surface facilities at Yucca Mountain pose less risk compared to nuclear powerplants.

Table 4-36 of the EIS describes earthquake accident scenarios with a recurrence frequency of once in 50,000 years. This is roughly equivalent to a Richter magnitude 7 earthquake occurring within 5 kilometers (3 miles) of Yucca Mountain with a mean peak ground acceleration of approximately 1.1*g*, where *g* is acceleration due to gravity (980 centimeters per second squared), at the repository level (not the surface). DOE considers these to be very conservative calculations that indicate the maximum impact of such an event.

As discussed in Section 3.1.3 of the EIS, Yucca Mountain consists of lithified volcanic ash that fell and flowed onto the site during eruptions from calderas to the north (see Figure 3-5 and Table 3-7). This explosive silicic volcanic activity occurred between about 14 million and 11.5 million years ago during the emplacement of large bodies of siliceous magma that formed in the middle and upper crust. These eruptions are part of the Southwestern Nevada volcanic field, which consists of five voluminous and many smaller eruptions that occurred on a regional scale. Smaller-volume basaltic volcanism began about 11 million years ago, and continued intermittently to between 70,000 and 90,000 years ago. This basaltic volcanism originated from much greater depths than the siliceous volcanism. The northeast-trending basaltic cinder cones in Crater Flat formed about 1 million years ago. DOE based its estimate of a 1-in-7,000 chance of a volcanic disruption at the repository during the next 10,000 years on detailed investigations of the volcanoes in the region. This estimate was recalculated in Section 3.1.3.1 of the Final EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000).

Intensive investigations by DOE found no evidence or credible mechanism to account for a rise in groundwater to flood the waste-emplacement horizon at Yucca Mountain. Szymanski (DIRS 106963-1989) proposed that during the last 10,000 to 1,000,000 years, hot mineralized groundwater was driven to the surface by earthquakes and volcanoes. This hypothesis goes on to suggest that similar forces could raise the regional groundwater table in the future and inundate the waste-emplacement horizon.

DOE requested the National Academy of Sciences to conduct an independent evaluation. The Academy concluded in its 1992 report (DIRS 105162-National Research Council 1992) that no known mechanism could cause a future inundation of the repository horizon. The features cited by Szymanski as proof of groundwater upwelling in and around Yucca Mountain are related to the much older (10 million to 13 million years old) volcanic process that formed Yucca Mountain and the underlying volcanic rocks. Major water table excursions (exceeding tens of meters) to the design level of the repository due to earthquakes are unlikely.

DOE scientists have estimated that the water table could rise by 50 to 130 meters (160 to 430 feet) under extremely wet climatic conditions. The regional aquifer has been estimated to have been a maximum of 120 meters (390 feet) above the present level beneath Yucca Mountain during the past million or more years based on mineralogic data, isotopic data, discharge deposit data, and hydrologic modeling. The occurrence of an earthquake under these extreme climatic conditions might cause an additional rise in the water table of less than 20 meters (66 feet), still leaving a safety margin of 20 meters (66 feet) or more between the water table and the level of the waste-emplacement drifts. The 1992 Little Skull Mountain earthquake (magnitude 5.6) raised water levels in monitoring wells at Yucca Mountain a maximum of less than 1 meter (3.3 feet) (DIRS 101276-O'Brien 1993). Water level and fluid pressure in continuously monitored wells rose sharply and then receded over a period of several hours to pre-earthquake levels. The water-level rise in hourly-monitored wells was on the order of centimeters and indistinguishable after 2 hours (DIRS 101276-O'Brien 1993).

Dublyansky (DIRS 104875-1998) proposed another line of data in support of the warm-water upwelling hypothesis. This study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. The report concludes that some of these crystals were formed by rising hydrothermal water and not by percolation of surface water. A group of Yucca Mountain Project scientists with expertise in hydrology, geology, isotope geochemistry, and climatology did not concur with Dr. Dublyansky's conclusions (DIRS 100086-Stuckless et al. 1998). Although DOE has disagreed with the central scientific conclusions of Dr. Dublyansky's report, DOE agreed to support continuing research. An independent investigation by Jean Cline, University of Nevada, Las Vegas, should be completed in Fiscal Year 2002. See Section 3.1.4.2.2 of the EIS for more information.

After closure of the repository, there would be a limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. The potential for gas transport of carbon-14 was analyzed because the repository host rocks are porous. Modeling shows that there would be negligible impacts to human health from releases of gas-phase carbon-14. Section 5.5 of the EIS contains more information on atmospheric radiological consequences.

DOE recognizes that some radionuclides and toxic chemicals could eventually enter the environment outside the repository. Modeling of the long-term performance of the repository, however, shows that the natural and engineered barriers at Yucca Mountain would keep the release of radioactive materials during the first 10,000 years after closure well below the limits established by 40 CFR Part 197 (see Sections 5.4 and 5.7 of the EIS for more information). Modeling also shows that the release of toxic chemicals would be far below the regulatory limits and goals established for these materials (see Section 5.6 of the EIS for more information).

The EIS addresses the performance of the repository for the 10,000-year regulatory period and the period between 10,000 years and one million years. DOE based its analysis of impacts on a state-of-the-art modeling technique that is internationally recognized as an adequate and proper approach. The results of this analysis, described in Chapter 5 of the EIS, indicate that impacts would be low and that health effects would be thousands of times less than natural incidences of health problems in the population.

7.5.3.4 Volcanism

7.5.3.4 (368)
<u>Comment</u> - EIS000045 / 0001
The data gathered by Nye County in its oversight program was not entered into this draft. An example is the geothermal activity found not too far from Yucca Mountain. The EIS does not even consider the risk of volcanic activity at Yucca despite Nye County's findings and the fact that there is a very young cinder cone from a recent eruption under 20 miles from Yucca Mountain.

<u>Response</u>
During the preparation of this EIS, DOE considered all pertinent data, including data from Nye County. Furthermore, DOE has supported Nye County with it's program (called the Early Warning Drilling Program) to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain, as well as the relationships among the volcanic, alluvial, and carbonate aquifers. Information from the ongoing site characterization program and from the performance confirmation program (if Yucca Mountain is approved for a repository), would be used in conjunction with that of the Early Warning Drilling Program to refine the Department's understanding of the flow and transport mechanics of the saturated alluvium and valley-fill material south of the proposed repository site, and to update conceptual and numerical models used to estimate waste isolation performance of the repository. When DOE published the Draft EIS, only limited information from the Early Warning Drilling Program was available. Since then, however, this program has gathered additional information (see Section 3.1.4.2.1 of the EIS).

A panel of recognized experts in volcanism reviewed extensive information on volcanic activity in the Yucca Mountain region to assess the probability of disruption of a repository at Yucca Mountain by a volcanic event. The results of the hazard assessment indicated that the aggregate expected annual frequency of intersection of the repository footprint by a volcanic event is 1.5×10^{-8}, or approximately 1 chance in 7,000 during the first 10,000 years after closure (1 chance in 70 million annually). This estimate was recalculated in Section 3.1.3.1 of the Final EIS to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000). The rocks at Yucca Mountain were formed 7 to 15 million years ago by large silicic ash flows that were erupted during a period of intense tectonic activity. The volcanism that produced these ash flows is complete and, based on the geology of similar volcanic systems in the Great Basin, additional large volume silicic activity is unlikely. Less explosive and much smaller volume basaltic volcanism in the Yucca Mountain region began about 11 million years ago as silicic eruptions waned and continued as recently as 70,000 to 90,000 years ago (see Section 3.1.3.1 of the EIS).

The EIS analyzes two disruptive volcanic event scenarios as part of the postclosure performance assessment—(1) the volcanic eruption release scenario or direct release scenario where radioactive material is transported directly to the surface and atmosphere by a magma or pyroclastic flow and (2) the igneous intrusion groundwater release or enhanced source term scenario where radioactive material is entrained in magma that remains in the emplacement drift. Section 5.7.2 of the EIS contains more information.

7.5.3.4 (975)
Comment - EIS000230 / 0004
Of further interest is the Long Valley Caldera in the Mammoth Lakes area. According to USGS's [US. Geological Survey's] website, the Yucca Mountain facility is in the path of ash flow when the caldera erupts. Also it may not be known when an eruption would occur. According to the USGS, there is an increased chance of an eruption occurring in the near future. A 5cm [centimeter] ash fall would occur at Yucca Mountain when an eruption occurs at the Long Valley Caldera. Such an ash fall would turn day into night as we witnessed after Mt. St. Helen erupted. The ash itself is highly corrosive causing severe damage to casks stored above ground, as well as disrupting transportation.

The current DEIS is deficient because it never considered the Long Valley Caldera and its eventual eruption.

Response
The EIS evaluated potential impacts from a regional volcanic eruption. Section H.2.1.3 of the EIS concludes that 3 centimeters (about 1.2 inches) is the maximum thickness of tephra (solid material; ash) from a "regional volcanic eruption, which is more likely," that could deposit on repository facilities. Analyses to date indicate that such an event would not affect structures such as the Waste Handling Building, where DOE would process casks.

The EIS analysis used the same data (DIRS 152166-Miller et al. 1982) presented on the U.S. Geological Survey Internet web site. The thickness-versus-distance curve shows that ash from the Long Valley Caldera/Mono-Inyo Volcanic area [250 kilometers (155 miles) from Yucca Mountain] would deposit about 1 centimeter (0.4 inch) of ash at the proposed repository. The same volume of material from an eruption in the closer Coso Volcanic Field [150 kilometers (93 miles) distant] would deposit 2 to 3 centimeters (0.8 to 1.2 inches) of volcanic ash at the repository (DIRS 102889-Perry and Crow 1987).

7.5.3.4 (1831)
Comment - EIS000206 / 0010
Question that is not answered by DOE: volcanic activity in the area appears to have been far more recent than previously estimated.

Response
Section 3.1.3 of the EIS describes the geologic setting of Yucca Mountain and the surrounding region in great detail, including the volcanic history of the region. The youngest volcanic center in the region is the Lathrop Wells cinder cone, which is between 70,000 to 90,000 years old.

7.5.3.4 (4535)
Comment - EIS001521 / 0048
Page 3-42--(Hydrologic Properties of Rock, second paragraph) What is an igneous versus volcanic flow? Is this referring to an igneous-intrusive sill? Or should the discussion center on the differences between ash-fall versus

ash-flow tuffs? Volcanic flows may be silicic to basaltic (or anything in between) in mineralogical composition, but igneous is not a correct descriptor.

Response
The point of this discussion was to differentiate between a hydrographic and stratigraphic unit. DOE has clarified the text of Section 3.1.4.2.2.

7.5.3.4 (5475)
Comment - EIS001887 / 0156
Page 3-24; Section 3.1.3.1 - Physiography - Potential for Volcanism at the Yucca Mountain Site

Again, there is uncertainty associated with the age of the Lathrop Wells volcano. The latest activity could have been thousands of years more recent than the 75,000 year age indicated.

Response
Studies at Lathrop Wells, combining geochronology and field studies, indicate that the Lathrop Wells cone formed during a single eruption about 80,000 years ago (DIRS 138732-Perry, Phillips, and Chung 1988). DOE has added information to Section 3.1.3.1 of the EIS to indicate the uncertainty of these dates.

7.5.3.4 (5484)
Comment - EIS001887 / 0154
Page 3-21; Section 3.1.3.1 - Physiography (Characteristic Landforms)

There is uncertainty associated with the age of the last eruption of the Lathrop Wells cone. The range of the uncertainty should be stated here.

Response
Studies at Lathrop Wells, combining geochronology and field studies, indicate that the Lathrop Wells cone formed during a single eruption about 80,000 years ago (DIRS 138732-Perry, Phillips, and Chung 1988). DOE has added information to Section 3.1.3.1 of the EIS to indicate the uncertainty of these dates.

7.5.3.4 (5487)
Comment - EIS001887 / 0157
Page 3-25; Section 3.1.3.1 - Physiography - Potential for Volcanism at the Yucca Mountain Site

The estimated probability of a dike disrupting the repository during the first 10,000 years after closure has uncertainty associated with it. The expert panel members' estimates of the annual probability ranged over about three orders of magnitude, and the probability indicated here represents an aggregation of the members' estimates.

Response
The objective of the expert elicitation on the volcanic hazards at Yucca Mountain was to assess the probability of disrupting the repository by a volcanic event, and to quantify the uncertainties associated with the assessment. In this context, "disruption" means the physical intersection of magma, such as a dike, with the repository, and "probability" refers to an annual frequency.

A major goal of the expert elicitation was to capture the uncertainties in the assessment, including uncertainties associated with the models used to represent the key physical controls on volcanism and the parameter values used in the models. The resulting probability distribution, therefore, provides a reasonable representation of the state of knowledge and uncertainty about the volcanic hazard at the Yucca Mountain site.

Expert elicitation concluded that the aggregate expected annual frequency of repository disruption by a dike is 1.5×10^{-8} for the repository design described in the Draft EIS, with a 90-percent confidence interval of 5.4×10^{-10} to 4.9×10^{-8}. The annual frequency of repository disruption was recalculated for the flexible design considered in the Final EIS and found to be 1.6×10^{-8} if contingency blocks are included in the calculation. The major contributors to the uncertainty in the frequency of disruptions are the statistical uncertainty in estimating the rate of occurrence of volcanic events and the uncertainty in modeling the spatial distribution of future events. Although there were major differences between the interpretations of the 10 panel members, most of the uncertainty in the computed frequency of intersection was due to the average uncertainty that an individual expert expressed in developing the appropriate model.

7.5.3.4 (6564)
Comment - EIS001632 / 0051
Page 5-44, first paragraph: It is difficult to understand the first part of this paragraph. Please explain the sentence: "Because of its low velocity, the magma would not be removed from the waste package."

Response
This is a valid point. The sentence in question is confusing and has been deleted from the EIS.

7.5.3.4 (7388)
Comment - EIS001957 / 0015
Section 3.1.3.1, Geology, Physiography, Potential for Volcanism at the Yucca Mountain Site – The narrative indicates that during 1995-96:

"...DOE convened the panel of recognized experts...to assess uncertainties associated with the data and models used to evaluate the potential for disruption of the potential Yucca Mountain Repository by a volcanic intrusion (dike). The panel estimated the probability of a dike disrupting the repository during the first 10,000 years after closure to be 1 chance in 7,000."

However, the draft EIS does not evaluate the effects from such a disruption occurring. No discussion is included as to the structural integrity of radioactive waste canisters if such an event should occur, and what such disruption might mean for the possibility of leakage and transport of radioactive constituents away from the proposed repository and into the regional groundwater flow systems.

Response
Section 5.7.2 of the Final EIS describes an igneous event that could disrupt the repository. The evaluation showed that it is unlikely that liquid magma or other igneous material would intersect the repository. However, because there is a finite probability of such an occurrence, it was analyzed. As described in Section 5.7.2.3 of the Final EIS, the mean annual probability of this event occurring is 1.6×10^{-8} during the next 100,000 years. The impacts from such an event are described in Section 5.7.2.3.

7.5.3.4 (7455)
Comment - EIS001969 / 0010
Page S-36, 5.4.1.3 [S.4.1.3] Geology, first paragraph.

Most of the faulting that affected Yucca Mountain occurred during the 11.4 to 14 Ma [million years ago] interval of volcanic activity and not subsequent to the activity, as stated in the text.

Response
DOE agrees that most of the faulting occurred during this period and Section S.4.1.3 of the EIS Summary has been changed to, "Yucca Mountain is a product of volcanic and seismic activity that occurred 14 million to 11.5 million years ago."

7.5.3.4 (7507)
Comment - EIS001969 / 0018
Page 3-21, last paragraph.

The statement, "Volcanic rocks younger than the Tertiary units...," is incorrect. Most of the volcanic rocks are Tertiary in age, including the Skull/Little Skull lava flows, the lava flow at the south edge of Crater Flat, the 10 Ma basaltic dike, and the 3.7-Ma cones and flows in Crater Flat.

Response
DOE has revised Section 3.1.3.1 of the EIS to state that volcanic rocks younger than Tertiary age pertain only to the four northeast-trending cinder cones in the center of Crater Flat, dated at about 1 million years old, and the Lathrop Wells basaltic cinder cone, dated at 70,000 to 90,000 years old.

7.5.3.4 (8828)
Comment - EIS000869 / 0009
Paragraphs one and two of S.4.1.3. Geology, address the lack of volcanic activity in the area. The Cascade mountain range was inactive until Mount St. Helens erupted in May 1980. There has also been increased volcanic activity worldwide. The assurances of "the chance of volcanic disruption ... during the first 10,000 years after closure would be 1 in 7,000" are probably similar to what residents of Mount St. Helens were told for years prior to the eruption. I believe that these are misleading numbers and assumptions on the geology of the Yucca Mountain area.

Response
DOE considered several types of volcanic disturbances and conducted extensive assessments for the EIS. The volcanic rocks exposed at Yucca Mountain formed between 7 and 15 million years ago during eruptions of large, silicic ash flows. The volcanism that produced these ash flows ended millions of years ago and, based on the geology of similar volcanic systems in the Great Basin, additional large-volume silicic activity is unlikely. Less explosive and much smaller-volume basaltic volcanism in the Yucca Mountain region began about 11 million years ago, as silicic eruptions waned, and has continued to as recently as 70,000 to 90,000 years ago. Based on these data, volcanic disruption of a repository at Yucca Mountain would be highly unlikely. The chance of a disruption at or near the repository would be 1 chance in 7,000 during the first 10,000 years after closure (1 chance in 70 million annually).

The volcanic history of Mount St. Helens is quite different from the volcanic history of the Yucca Mountain region. Mount St. Helens is a large volcano along the Pacific "Ring of Fire." It is associated with a highly active subduction zone. Yucca Mountain, on the other hand, is within a region of crustal extension. The estimated rate of convergence of the Juan de Fuca Plate with western Washington is about 4 centimeters (1.6 inches) per year compared to a strain rate of 0.1 millimeter (0.004 inch) per year or less in the Yucca Mountain region (DIRS 118952-Savage, Svarc, and Prescott 1999). While Mount St. Helens is a relatively young volcano (40,000 to 50,000 years old), it has an extensive history of eruptions. The penultimate major eruption occurred in 1800 and, as the U.S. Geological Survey pointed out in an article on the Internet, the "eruption in 1980 came as no surprise" [http://vulcan.wr.usgs.gov/Volcanoes/ PacificNW/AGU-T106/msh.html]).

7.5.3.4 (10424)
Comment - EIS001927 / 0031
The Western Shoshone Nation, which by the way has the rightful claim to Yucca Mountain by the 1863 Treaty of Ruby Valley which the U.S. government signed, has a different name for the site. It translates as "Serpent Swimming Westward." Indeed, global positioning satellite studies, published in Science magazine in 1998, have confirmed that the crust at Yucca Mountain is expanding westward, and at a rate an order of magnitude greater than previously believed. (Another recent finding, published in Scientific American in the last month or two, is that plutonium is much more soluble in water than previously believed, which may account for its unexplained mobility in the soil of the Nevada Test Site. This finding challenges the very concept of long-term geologic isolation of plutonium. This issue should be addressed in the EIS, for it holds great import for the ability of Yucca Mountain to contain plutonium).

This observation is consistent with the presence of a magma pocket beneath Yucca Mountain. Indeed, standing atop Yucca Mountain, one can see a line of lava cones extending westward. The youngest cone is closest to Yucca Mountain. This too is striking evidence of the presence of a magma pocket beneath Yucca Mountain – like the formation of the Hawaiian Islands, these lava cones are like the squirts from a gigantic subterranean pastry bag.

Perhaps the biggest danger from the presence of lava beneath Yucca Mountain is the possibility that it could drive hot groundwater up into the repository, flooding the waste casks. Indeed, recent analyses of gas trapped in crystals that are abundant inside Yucca Mountain shows that these crystals were formed by HOT water welling up into the mountain from below. The question scientists are currently examining is how recently this took place. Hot water flooding the repository could quickly deteriorate the casks, and could even lead to a steam or chemical explosion or nuclear criticality event. In any case, the radiation release would be catastrophic.

Response
The geodetic study reported in the March 1998 issue of Science (DIRS 103485-Wernicke et al. 1998) was based on baseline measurements using the Global Positioning System from 1991 to 1997 at five stations in the Yucca Mountain area (discussed in Section 3.1.3.3 of the EIS). While the authors discussed the possible effects on their network from displacements associated with the June 1992 Little Skull Mountain earthquake, they did not correct the station-to-station distances for earthquake displacements.

In May 1998, scientists from the U.S. Geological Survey used the Global Positioning System to resurvey a network of 14 geodetic stations originally installed in 1983 (DIRS 118952-Savage, Svarc, and Prescott 1999). Wernicke et al. (DIRS 103485-1998) used only two of the 14 stations in their study. Based on the greater number of stations, the longer survey period (1983 to 1998), and the removal of the effects of the 1992 Little Skull Mountain earthquake, the scientists concluded (DIRS 118952-Savage, Svarc, and Prescott 1999) that the strain rate in the Yucca Mountain region is considerably less (by a factor of 20 or more) than the rate reported by Wernicke et al. (DIRS 103485-1998). The survey results are consistent with a large body of geologic data collected in the Yucca Mountain region over the past two decades.

Wernicke et al. (DIRS 103485-1998) speculated that magmatic inflation at depth could be the cause of the high strain accumulation across the Yucca Mountain area. They pointed to a seismic tomographic study by Oliver, Ponce, and Hunter (DIRS 106447-1995) that hinted at the presence of a low-velocity zone beneath Crater Flat that could be consistent with basaltic magma. A subsequent study (DIRS 105358-Biasi 1996), based on more accurate seismic arrival times and a deeper inversion model than that used by Oliver, Ponce, and Hunter (DIRS 106447-1995), demonstrated conclusively that there is no low-velocity zone under Crater Flat or Yucca Mountain that would suggest a major volcanic hazard.

The line of cones in Crater Flat to the west of Yucca Mountain trends north-northeast. From south to north the line consists of Little Cone, Red Cone, Black Cone, and Makani Cone (DIRS 151945-CRWMS M&O). These cones are the sites of basaltic eruptions that are approximately 1 million years old (DIRS 151945-CRWMS M&O 2000). The youngest cone in the area is near Lathrop Wells; it erupted between 70,000 and 90,000 years ago.

Dublyansky (DIRS 104875-1998) proposed another line of evidence in support of the warm-water upwelling hypothesis (discussed in Section 3.1.4.2.2 of the EIS). This study involved fluid inclusions in calcite and opal crystals deposited at Yucca Mountain. It concludes that some of the crystals were formed by rising hydrothermal water and not by the percolation of surface water. A group of project scientists with expertise in hydrology, geology, isotope geochemistry, and climatology did not concur with the conclusions in the Dublyansky report (DIRS 100086-Stuckless et al. 1998). Although DOE has disagreed with the central scientific conclusions in that report, it did agree to support continuing research. Section 3.1.4.2.2 contains more information.

7.5.3.4 (10707)
Comment - EIS002197 / 0003
The site is possibly situated on the Pacific Ring of Fire. I bring that up because you have your Mt. St. Helens explosions and you can come all the way around and do you realize southwest of here is a big field of magna?

We don’t even go to visit it, but you know there’s been volcanic activity in this region many, many times.

We also know about the fissures, we know about the earthquakes, we know about all that stuff.

We don’t know how hot stuff can stay a solid. We have no idea the exponential rate of putting hot with hot, with hot with hot, and what it might do.

Response
Yucca Mountain is in the southern Great Basin, on a block of continental crust. The “Ring of Fire,” which is a relatively narrow belt of crustal subduction along the edge of the Pacific basin, has a much higher rate of faulting and volcanic activity compared to the Yucca Mountain area. The explosive nature of eruptions at Mt. St. Helens is

characteristic of the Ring of Fire. In contrast, the most recent volcanic eruption near Yucca Mountain occurred near Lathrop Wells between 70,000 and 90,000 years ago where small volumes of basalt and ash were erupted. Wernicke et al. (DIRS 103485-1998) speculated that magma at depth below Yucca Mountain could drive the high strain accumulation across the area. They pointed to an early seismic tomographic study by Oliver, Ponce, and Hunter (DIRS 106447-1995) that hinted at the presence of a low-velocity zone beneath Crater Flat that could be consistent with basaltic magma. A subsequent study by Biasi (DIRS 105358-1996), based on more accurate seismic arrival times and a deeper inversion model than that used by Oliver, Ponce, and Hunter (DIRS 106447-1995), demonstrated rather conclusively that there is no low-velocity zone under Crater Flat or Yucca Mountain that would suggest a major volcanic hazard.

DOE has been evaluating several heat management strategies for the proposed repository at Yucca Mountain. None of the design alternatives would produce heat that would increase the potential volcanic hazard at the site.

7.5.3.4 (12413)
Comment - EIS001888 / 0429
[Clark County summary of comments it has received from the public.]

Commenters also requested deterministic evaluations of both direct and indirect effects on the repository from volcanic activity.

Response
Section 5.7.2 of the Final EIS describes an igneous event that could disrupt the repository. The evaluation showed that it is unlikely that liquid magma or other igneous material would intersect the repository. However, because there is a finite probability of such an occurrence, it was analyzed. As described in Section 5.7.2.3 of the Final EIS, the mean annual probability of this event occurring is 1.6×10^{-8} during the next 100,000 years. The impacts from such an event are described in Section 5.7.2.3.

7.5.3.4 (12445)
Comment - EIS001898 / 0015
Additional documentation or analysis should be provided in the FEIS to support the characterization of impacts and the description of environmental parameters in some areas of the FEIS.

Section H.2.1.3 (Potential Repository Accident Scenarios: Analytical Methods and Results External Events) of the DEIS concludes that 3cm is the maximum thickness of volcanic tephra that could be deposited on repository facilities from a basaltic volcano that erupts within the area around the proposed repository site. The basis for this conclusion is a statement (DOE, 1998) that 3cm of volcanic tephra is the worst-case event being considered. The conclusion appears not to be supported by data or analyses.

Reference:

U.S. Department of Energy. Viability assessment of a repository at Yucca Mountain. *Volume 2: Preliminary Design Concept for the Repository and Waste Package.* DOE/RW-0508. Washington, DC: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. 1998.

Response
The EIS evaluated potential impacts from a regional volcanic eruption. Section H.2.1.3 of the EIS concludes that 3 centimeters (about 1.2 inches) is the maximum thickness of tephra (solid material; ash) from a "regional volcanic eruption, which is more likely," that could be deposited on repository facilities. Analyses to date indicate that such an event would not affect structures such as the Waste Handling Building, where DOE would process casks.

The EIS analysis used a thickness-versus-distance curve from Miller et al. (DIRS 152166-1982). This curve shows that ash from the Long Valley Caldera/Mono-Inyo Volcanic area [about 250 kilometers (155 miles) west of Yucca Mountain] would deposit about 1 centimeter (0.4 inch) of ash at the proposed repository. The same volume of material from an eruption in the closer Coso Volcanic Field [about 150 kilometers (93 miles) southeast of Yucca Mountain] would deposit 2 to 3 centimeters (0.8 to 1.2 inches) of volcanic ash at the repository (DIRS 102889-Perry and Crow 1990).

7.5.3.4 (12735)
Comment - EIS001022 / 0001
One important concern is the possibility of volcanic activity. Yucca Mountain itself was formed by a violent series of eruptions 12 to 15 million years ago. The last violent eruption was 8.5 million years ago, but there have been small peaceful eruptions, the last one only 10,000 years ago. The two nearest cones are 9 and 15 km from the boundary of the waste emplacement area. Based on this information, many questions arise. Could a volcano erupt while the waste is still active? What would be the effects?

The area was assessed as low risk, but there has been an important study since then. Geologist Brian Wernicke and colleagues conducted a study using the Global Positioning System (GPS). Between 1991 and 1997, they used the GPS to measure crustal expansion between two different satellites on Yucca Mountain. This study produced results very different than the results from previous studies. According to previous studies, the distance between the two satellites was not supposed to change at all. However, the distance between the two satellites changed 1.7 mm, showing that the movement of the Earth's crust in this area is much greater than previously thought and accelerating. Wernicke suggested that the possibility of a volcano could be ten times higher than previously thought.

Because the measurement values were so small, this study does not provide conclusive proof, but it does raise many important questions. More research is needed to determine whether this new study is accurate. This evidence is consistent with the possibility of a magma pocket under Yucca Mountain. With the new evidence, the low-risk status is under question. If these findings are correct, there is a much greater chance of volcanic eruptions than previously thought. This raises important questions about the safety of our nuclear wastes. The Department of Energy is planning to send 70,000 tons of nuclear waste that will remain radioactive in Yucca Mountain for over 10,000 years. Before they do this, this study must be pursued further. The possible effects of a volcano through Yucca Mountain are too dangerous to ignore. We need to do more research about this possibility.

The Western Shoshone tribe, that has a rightful claim to this land, have another name for this land. They call it "Serpent Swimming West." This could be a metaphor for magma swimming under Yucca Mountain. Along with the recent study, ancient wisdom speaks of the danger of radioactive waste at Yucca Mountain. Both ancient wisdom and recent studies are warning us to proceed with caution. If this study is proven correct, sending radioactive waste to Yucca Mountain is a dangerous choice. This study shows how more research is needed before we could send waste to Yucca Mountain.

Response
The most recent volcanic eruption in the Yucca Mountain region occurred at Lathrop Wells between 70,000 and 90,000 years ago. DOE based the estimated age of this eruption on several geochronologic dating techniques that indicate that the earlier estimate of 10,000 years is not valid. DOE has updated this material in Section 3.1.3.1 of the Final EIS.

The postclosure performance assessment in Section 5.7.2 of the EIS analyzes two disruptive volcanic event scenarios. The first is the volcanic eruption release scenario or direct release scenario, where radioactive material is transported directly to the surface and atmosphere by a magma or pyroclastic flow. The second, called the igneous intrusion groundwater release or enhanced source term scenario, is where radioactive material is entrained in magma that remains in the emplacement drift. The analyses include a discussion on the structural integrity of the waste packages, and what these scenarios could mean for the possibility of leakage and transport of radioactive constituents away from the proposed repository. DOE has updated this material in the EIS.

The geodetic study reported in the March 1998 issue of *Science* (DIRS 103485-Wernicke et al. 1998) was based on baseline measurements obtained from 1991 to 1997 using the Global Positioning System at five stations in the Yucca Mountain area. While the authors discussed possible effects on their network from displacements associated with the June 1992 Little Skull Mountain earthquake, they did not correct the station-to-station distances for earthquake displacements.

In May 1998, scientists from the U.S. Geological Survey used the Global Positioning System to resurvey a network of 14 geodetic stations originally installed in 1983. Wernicke et al. (DIRS 103485-1998) used two of the 14 stations in their study. Based on the larger number of stations, the longer survey period (1983 to 1998), and the removal of the effects of the June 1992 Little Skull Mountain earthquake, the U.S. Geological Survey scientists concluded

(DIRS 118952-Savage, Svarc, and Prescott 1999) that the strain rate in the Yucca Mountain region is significantly less (by a factor of 20 or more) than the rate reported by Wernicke et al. (DIRS 103485-1998). The results of the U.S. Geological Survey are consistent with a large body of geologic data and fault-trenching investigations in the Yucca Mountain region over the past two decades.

Wernicke et al. (DIRS 103485-1998) speculated that magmatic inflation at depth could be the cause of the high strain accumulation across the Yucca Mountain area. They pointed to an early seismic tomographic study by Oliver, Ponce, and Hunter (DIRS 106447-1995) that hinted at the presence of a low-velocity zone beneath Crater Flat that could be consistent with basaltic magma. A subsequent study by Biasi (DIRS 105358-1996), based on more accurate seismic arrival times and a deeper inversion model, demonstrated rather conclusively that there is no low-velocity zone under Crater Flat or Yucca Mountain that would suggest a major volcanic hazard.

DOE is continuing to fund studies on crustal strain in the Yucca Mountain region through a cooperative agreement with the University of Nevada. Dr. Wernicke, the principal investigator of one study, recently estimated in a quarterly report to the DOE that conclusions from this study would be available in 2002. This study involves 30 geodetic monument sites with continuous GPS measurements, which is a major improvement over the study reported in *Science* (DIRS 103485-Wernicke et al. 1998).

7.5.3.4 (13220)
Comment - 010244 / 0019
The SDEIS should consider what, if any, effect closer spacing of waste packages has upon the probability and consequence of a volcanic dike encountering one or more waste packages.

Response
These concepts are addressed in both the Draft EIS and the Final EIS. In very general terms, spacing the waste packages further apart increases the repository footprint and, as a result, increases the associated probability of a volcanic dike intersecting the footprint. (The probability of such an event occurring, however, is very small and the change in probability is also very small.) On the other hand, putting waste packages closer together would decrease the footprint size (and the probability of a volcanic dike intersection), but would increase the potential for waste package damage should such an event occur. That is, an intersecting volcanic dike would be more likely to come into contact with waste packages the more tightly grouped they are.

Section 3.1.3.1 of the EIS describes the probability of a volcanic dike intersecting the footprint area of the proposed repository. The Draft EIS identified a potential of 1 chance in 7,000 that such an event would occur during the first 10,000 years after repository closure. A revised estimate of 1 chance in 6,300 during the first 10,000 years is included in the Final EIS as a result of a recalculation to account for changes in the layout of the proposed repository and to include contingency blocks in addition to the primary repository block. As would be expected, the larger the size of the repository, the higher the probability that a volcanic dike could intersect the footprint (even though this probability is still very small).

Potential consequences from volcanic activity are described in Chapter 5 of the EIS (Environmental Consequences of Long-Term Repository Performance). Modeling long-term performance of the repository begins with the probability value for a volcanic dike to intersect the repository footprint, then incorporates estimates of how such an intrusion could affect the repository drifts and waste containers. With approximately 80 meters between drifts, a dike could intersect the repository without contacting either the tunnels or the containers, but it could also enter the drifts and breach or otherwise damage waste containers. Because of the uncertainties involved in evaluating how a volcanic dike could affect the repository, sensitivity analyses were performed that include a range of intrusion scenarios where the number of drifts and waste packages that could be involved are varied. The long-term performance analysis also covers the fate of contaminated materials released from containers as a result of the very low probability of a volcanic dike intrusion. This includes materials that could be immediately released into the air and the environment from magma and ash reaching the surface, as well as materials slowly migrating to groundwater if the igneous activity remained below the surface. Results of these analyses are summarized in the EIS, but the supporting documents, referenced in Chapter 5 and Appendix I of the EIS, should be reviewed for detailed information on how volcanic disturbances were evaluated.

7.5.3.5 Minerals and Energy

7.5.3.5 (4952)
Comment - EIS001946 / 0010
There are numerous technical concerns regarding Yucca Mountain:

The presence of mineral resources could result in human intrusion into the repository.

Significant scientific uncertainty surrounds this issue. It is not adequately explored in the DEIS.

Response
Section 5.7.1 of the EIS examines the consequences of inadvertent and deliberate intrusion of the repository by drilling. With regard to the inherent uncertainty associated with geologic data, analyses, and models, and the confidence in estimates of long-term repository performance, Section 5.2.4 of the EIS explains how DOE dealt with these issues.

7.5.3.5 (5492)
Comment - EIS001887 / 0160
Page 3-30; Section 3.1.3.4 - Mineral and Energy Resources

The EIS should show the locations of existing mining claims in the proposed withdrawal area, despite DOE's belief that economic mineral potential of the area is low.

Response
Section 3.1.1.2 of the EIS mentions that there are unpatented mining claims and one patented mining claim in the right-of way reservation granted to DOE by the Bureau of Land Management for site characterization. This right-of-way is roughly coincident with the withdrawal area shown in Figure 1-6 of the EIS.

Because the status of unpatented claims can change rapidly, it was decided not to identify the location of unpatented claims in the EIS or to develop a strategy for dealing with claimants. If existing unpatented claims were still viable at the time of a land withdrawal, it is reasonable to assume that such claims could be obtained through compensation or otherwise dealt with before repository closure. Because the exact number and location of unpatented claims does not affect the EIS analyses, the addition of this information serves no purpose at this time.

The single patented mining claim in the area is used to mine volcanic cinders for raw material to manufacture cinderblocks (see Section 3.1.1.3 of the EIS). It is expected that this claim would be exhausted before permanent closure of the repository.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Congress can authorize and direct a permanent withdrawal of lands such as those required for a repository at Yucca Mountain. The extent and conditions of the withdrawal would be determined by Congress.

7.5.3.5 (5493)
Comment - EIS001887 / 0161
Page 3-31; Section 3.1.3.4 - Mineral and Energy Resources

The text should read, "...no currently economic deposits.." As any geologist will tell you, technology and demand can change a currently uneconomical deposit into an economical one almost overnight.

Response
DOE agrees that the economics of a mineral or energy deposit can change over time. However, Section 3.1.3.4 of the EIS asserts that the potential for economically useful mineral or energy resources is low, and would continue to be low for the foreseeable future.

7.5.3.5 (7574)
Comment - EIS001969 / 0033
Page 3-30, Section 3.1.3.4 Mineral and Energy Resources.

There is no discussion of energy resources in this section. The Yucca Mountain site is about 200 km SW of producing oil fields in Railroad Valley (one of two valleys in the state that have produced commercial oil). Published literature on the presence or absence of oil resources in the Yucca Mountain/NTS area include Chamberlain (1991 AAPG abstract), who suggested that Yucca Mountain is situated over a billion-barrel oil field, and Trexler and others (1996, AAPG Bulletin v. 80, no.1), who disputed this, as did Grow and others (Hi-Level Waste Proceedings, 1994). Although it appears that there is a low potential for mineral and energy resources in the context of today's recovery technology, a discussion of the potential resources should be included here.

Response
The EIS presents the results of various investigations on mineral and energy resources. DOE considers the likelihood of finding oil or gas to be low in the vicinity of the proposed repository. Drilling of numerous boreholes to depths beyond 1829 meters (6,000 feet) in the area found no indications or shows of oil of gas. Therefore, DOE decided not to include a detailed discussion of mineral and energy resource potential in the EIS, but rather to refer the reader to the numerous references that discuss these issues. This approach is consistent with the regulations of the Council on Environmental Quality [40 CFR Part 1501.7(a)(3)] that direct agencies to identify and eliminate from detailed study those issues which are not significant.

7.5.3.5 (9793)
Comment - EIS001888 / 0378
[Clark County summary of comments it has received from the public.]

Two commenters requested that the EIS assess the impacts to mineral exploration and development from the withdrawal of lands for the repository.

Response
Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of a specific agency. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as that needed for the proposed Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. Regulations issued by the Nuclear Regulatory Commission (10 CFR Part 63) require that the repository operations areas and postclosure controlled areas be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise. If Congress approved the withdrawal of lands for the repository, any other use of those lands would be subject to conditions of the withdrawal.

7.5.3.5 (13455)
Comment - 010296 / 0041
As noted on page 3-18, the titanium drip shields would not be needed until repository closure. However, page 3-19 notes that the titanium for drip shields would require from 47,000 to 66,000 tons of titanium, depending on spacing between waste packages. The annual requirement would be almost 8 percent of current U.S. production capacity. This is a huge percentage of a commodity supply, and methods to assure availability of supply, etc. should be reviewed. The environmental impacts of mining, smelting and purifying such a volume are large, and especially considering that it will be needed at a time when the easiest supplies have already been produced. The reference in the DSElS is to a 1997 Minerals Yearbook.

The FEIS should have an analysis of titanium availability, deposits, price trends, etc. to demonstrate when the optimum time to stockpile titanium will be, the price, etc. Alloy-22 and titanium drip shield performance are critical elements of the engineered barriers, limiting exposure especially in the l0,000-year time frame. For this reason, work needs to continue on Alloy-22 corrosion and decay experiments. There is substantial risk regarding availability of titanium 100s of years in the future, and a strategic assessment of titanium use, capability, reserves, etc. should be undertaken. The YMP may need a strategic titanium reserve to assure the availability of titanium when it is needed. The environmental impact of titanium mining and recovery were not addressed.

Response
DOE recognizes that a substantial amount of titanium would be required for the drip shields. The specific impacts of acquiring the titanium were not examined in the Supplement to the Draft EIS because this material would not be required for almost 100 years. As the repository program continues to evolve, the impacts of acquiring titanium would, as appropriate, be examined in future National Environmental Policy Act documents when further information became available.

7.5.4 BIOLOGY AND SOILS

7.5.4 (341)
Comment - EIS000052 / 0002
Microscopic parasite was discovered in the Yucca Mountain proposed Repository site. Are they harmful to this project?

Response
There are no known microscopic parasites in Yucca Mountain, but there are bacteria. DOE considered the possible effects of bacteria and of microbial communities in general on waste packages in the calculation of rates at which those packages could degrade. This was part of the near-field geochemistry model used to predict long-term performance of the repository in Chapter 5 of the EIS. The environmental consequences of long-term repository performance described in Chapter 5 include the possible effects of microbes on the project, which would be negligible.

7.5.4 (1131)
Comment - EIS000270 / 0014
Factors that give rise to public concerns about and opposition to approval of the Yucca Mountain site include:

Failure to provide for the protection of all components of the biosphere -- of the environment for its own sake -- from radiation-related harm.

Response
Sections 4.1.4 and 5.9 of the EIS examine potential impacts to biological resources for repository operations and for long-term repository performance, respectively. DOE expects impacts to biota to be low or very low. The analyses looked at potential impacts to individual members of threatened or endangered species such as the desert tortoise population and populations of other organisms. Current recommendations from national and international radiation protection advisory organizations (DIRS 157314-NCRP 1991; DIRS 101836-ICRP 1991; DIRS 101075-ICRP 1977) indicate that if humans are protected from radiation, other biota in the same area with similar exposure pathways are also protected. This is based on extensive scientific observations showing that more developed organisms (that is, humans) are more sensitive to radiation than less developed organisms. DOE has determined that radiation effects to plants and animals would be unlikely because the dose in all cases would be much lower than the 100-millirad-per-day level at which there is no convincing evidence that chronic radiation exposure would harm plant or animal populations (DIRS 103277-IAEA 1992).

7.5.4 (1508)
Comment - EIS000505 / 0008
We find many problems with the DEIS, factors that give rise to public concerns about opposition to approval of the Yucca Mountain site for example failure to provide for the protection of all components of the biosphere, of the environment for its own sake, from radiation related harm, failure in dose calculation to account for the addictive, multiplicative and synergistic relationship of radiological and other biologically hazardous pollutant factors and conditions ultimately affecting recipients.

Response
Sections 4.1.4 and 5.9 of the EIS examine potential impacts to biological resources for repository operations and for long-term repository performance, respectively. DOE expects impacts to biota to be low or very low. The analyses looked at potential impacts to individual members of threatened or endangered species such as the desert tortoise population and populations of other species. Current recommendations from national and international radiation protection advisory organizations indicate that if humans are protected from radiation, other biota in the same area